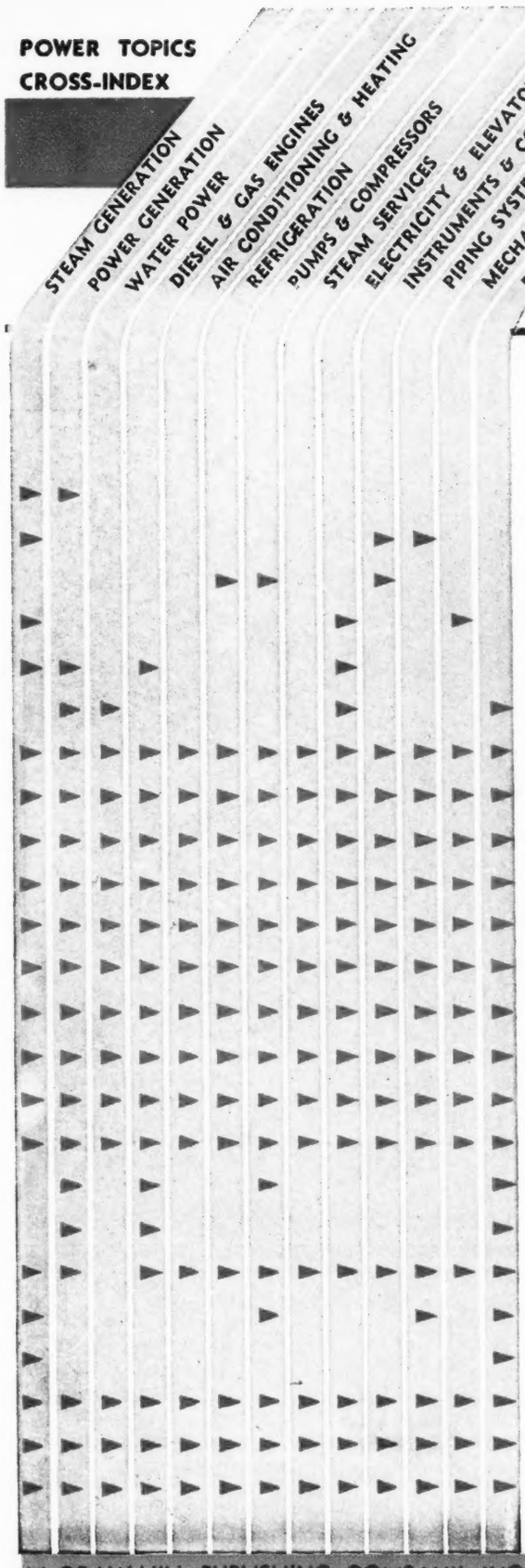

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POWER

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JUNE, 1937

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POWER

A McGRAW-HILL PUBLICATION—ESTABLISHED 1882—PHILIP W. SWAIN, EDITOR

Speaking of Power . . .

MAGIC—On a recent 2-week trip through the Midwest, I visited the plants of many manufacturers and saw much of interest. Here's a sample: In the Chicago laboratory of National Aluminate Corporation Dr. P. G. Bird, research director, showed me some spectacular results.

The story runs like this: For many years water has been softened by chemical means, but sodium could be removed only by evaporation, it was believed. This is no longer true; Dr. Bird and his associates have learned how to do the job chemically. Semi-commercial equipment and materials have already been tested.

There are two steps, involving so-called "exchangers," superficially like zeolites, but organic. First the raw water goes to the "acidic exchanger", which replaces the positive ions in the impurities with hydrogen ions. Leaving this exchanger, water is completely soft, but acidic. It goes next to the "basic exchanger." Here the negative ions (for example, the chlorine of HCl) are replaced by hydroxyl ions from the exchange substance.

This double shuffle of atomic partners is the new chemical magic by which water is freed from practically all dissolved solid impurities. Here we see, in the making, a purely chemical process which may soon compete with the multi-effect evaporator in the complete purification of boiler-feed makeup.

NO WINDOWS—Another vivid impression of National Aluminate is the windowless office and laboratory. "So what?" is the average man's reaction to the windowless idea, but he gets the point when he goes through such a building—controlled atmosphere plus controlled light. Temperature, humidity and light are determined not by season, hour or weather, but solely by the wishes of the occupants. Each room has its individual air-conditioning control and is flooded with artificial sunlight. Rooms can be located anywhere.

In the basement is the nerve center, with banks of conditioning and control equipment, neat as a pin.

Here is the building of the future, a clear indication of the increasing importance of the engineer in our civilization.

JOB PLUS—W. W. Crawford, president of Edward Valve, spent hours showing me around his plant at East Chicago. He certainly had a real understanding of the precision equipment in his tool room and physical and chemical laboratories—also of the lathes, millers, automatics and special tools in the factory. Much of the production I saw at Edward Valve was for severe service, involving such special materials as Monel, stainless, Stellite, nickel steel, Tobin bronze, etc. Mr. Crawford, incidentally, is a photographic fan, with an elaborate equipment of cameras, lenses and filters.

WATERFRONT—At the plant of The Hays Corporation in Michigan City, Ind., Phil Sprague, president, had much of interest to show me. This included the town, which is blessed with a fine waterfront on Lake Michigan, a new yacht basin, a zoo and a fine residential district.

Back in the plant Mr. Sprague demonstrated the Orsatomat. It replaces the old-style Orsat. No valves to manipulate; after the sample is in you merely tip the box back and forth and read the CO_2 on a big dial.

AND TELESCOPES—In this plant, as in others, you see the useful byproducts of hobbies. The company needed special lenses. One of the men could grind them. Incidentally, I saw a Pyrex disk ready to grind into the mirror of a reflecting telescope.

Which reminds me that other workmen (and executives) have made hobbies of telescopes. You can see their handiwork at Warner and Swasey (Cleveland), Jones and Lamson (Springfield, Vt.), Yarnall-Waring (Philadelphia) and elsewhere. Another proof that the machine age has not killed the old-time spirit of craftsmanship.

TREES AND TRAPS—Then there was the very neat plant of the Armstrong Machine Works, Three Rivers, Mich. Tom Rea, sales manager, showed me the works. Every now and then you see a place like that—a factory that is not a "factory" in a town that is not a "factory town". Neat and clean, inside and out, bowered in trees, this was a place to live while you work.

OTHER SPOTS—I visited many other manufacturers in Chicago, Mishawaka, Kalamazoo, Grand Rapids, Indianapolis and Pittsburgh. No space to tell of them here; perhaps later.

JEWELRY—But I must pass along the story I heard of the 28-ft. high smoke stack that cost $28,000. Built of precious tantalum, it carries nitrous fumes from a chemical plant. Diameter 30 in., thickness 1/100 in. . . . . P.W.S.

Logan's Double-Shell Turbine

Appalachian Electric Power Co.'s 40,000-kw., 3,600-r.p.m. topping turbine adds 90% more capacity to Logan station but increases total fuel consumption only 3%. The new unit operates at 1,250 lb. pressure and 925 F.

By G. B. Warren
Designing Engineer, General Electric Co.

DEVELOPMENT of the steam-turbine power plant over the past 40 years has been largely that of designing and building for ever-higher pressures, temperatures, speeds and capacities. Each increase has resulted ultimately in reduced fuel, operating, and capital charges per unit of output. The new 40,000-kw. 3,600-r.p.m., hydrogen-cooled, superposed turbine-generator unit, operating at 1250 lb. per sq. in. pressure and 925°F. initial temperature installed at Logan Plant of Appalachian Electric Power Co. represents the latest series of steps in this progressive development.

The generator for this unit, operating in hydrogen and having an efficiency close to 99%, alone makes possible turbine units for this capacity, speed, and efficiency. Development of these large 3,600-r.p.m. generators has opened up a whole new field in design of highly efficient, dependable, low-cost, superposed turbines of a size great enough to interest the public-utility industry.

By 1925 it appeared that the limit of temperature, about 750°F., had been reached with the materials then available for turbine construction. Research work on an intensive scale was started shortly thereafter and has been continued steadily since. The result has been a steadily increasing knowledge of the behavior of materials at high temperatures, of the working stresses which can be permitted, and of the specific heat treatments to which the materials should be subjected to permit minimum possible distortion in service at the higher temperatures demanded by the industry.

Development of High-Temperature Designs

During and following 1931, the General Electric Co. took advantage of the lull in business activities and undertook the design of a turbine for steam conditions of 1,200 lb. and 1,000°F., using materials then available or which it could be predicted would be available shortly.

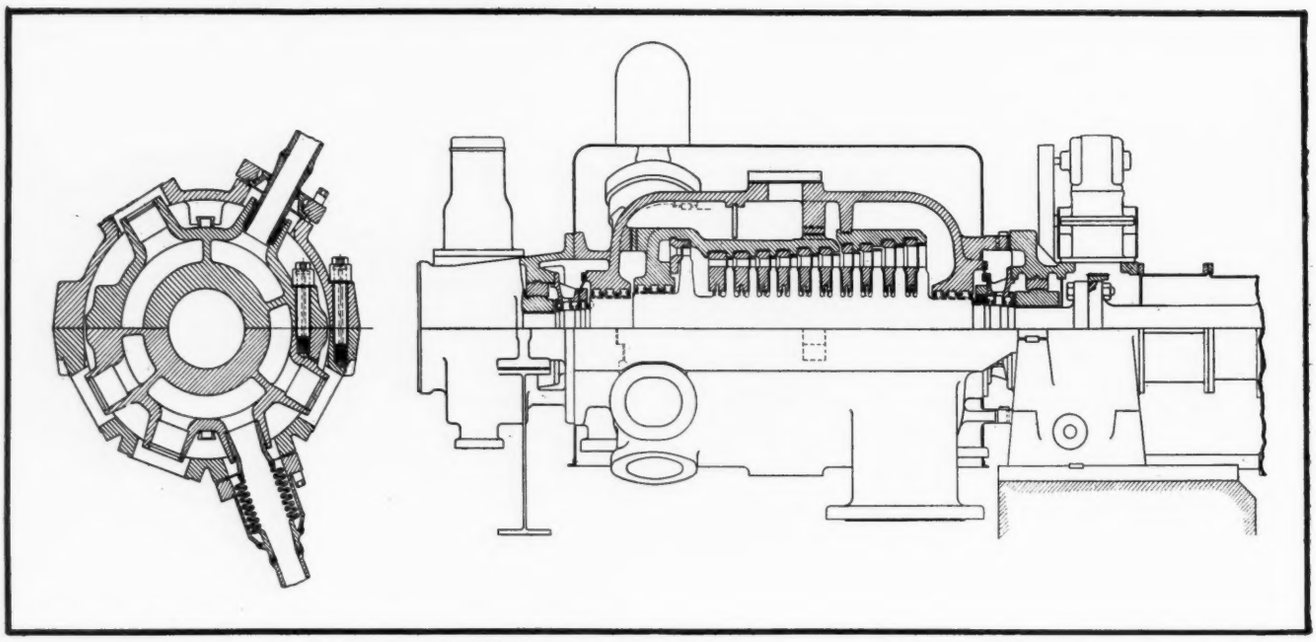
In this study, three types of turbines were finally developed, any one of which it was felt would meet this situation. Of the three, that having a "double shell" seemed to combine the largest number of advantages.

Several years ago, engineers of the American Gas & Electric Co. began to study the possibilities of superposing high-pressure and high-temperature turbines on existing stations. By 1935, it appeared that the first plant on their system to install such equipment would be the Logan Plant of Appalachian Electric Power Co. This was a logical carrying-out of a policy of pioneering which this group had been following for a number of years. Logan was particularly suited to superposing inasmuch as additional power was required, and the limit of condensing facilities had been reached. Low-cost coal was available, so reducing the cost of fuel was not a predominating factor.

This study[1] called for the largest 1,200-lb., 925°F., 3,600 r.p.m. turbine-generator which could then be built. The rating was finally set at 40,000

[1] Mechanical Engineering, Sept., 1936.

Fig. 1—Transverse and longitudinal sections of the Logan turbine



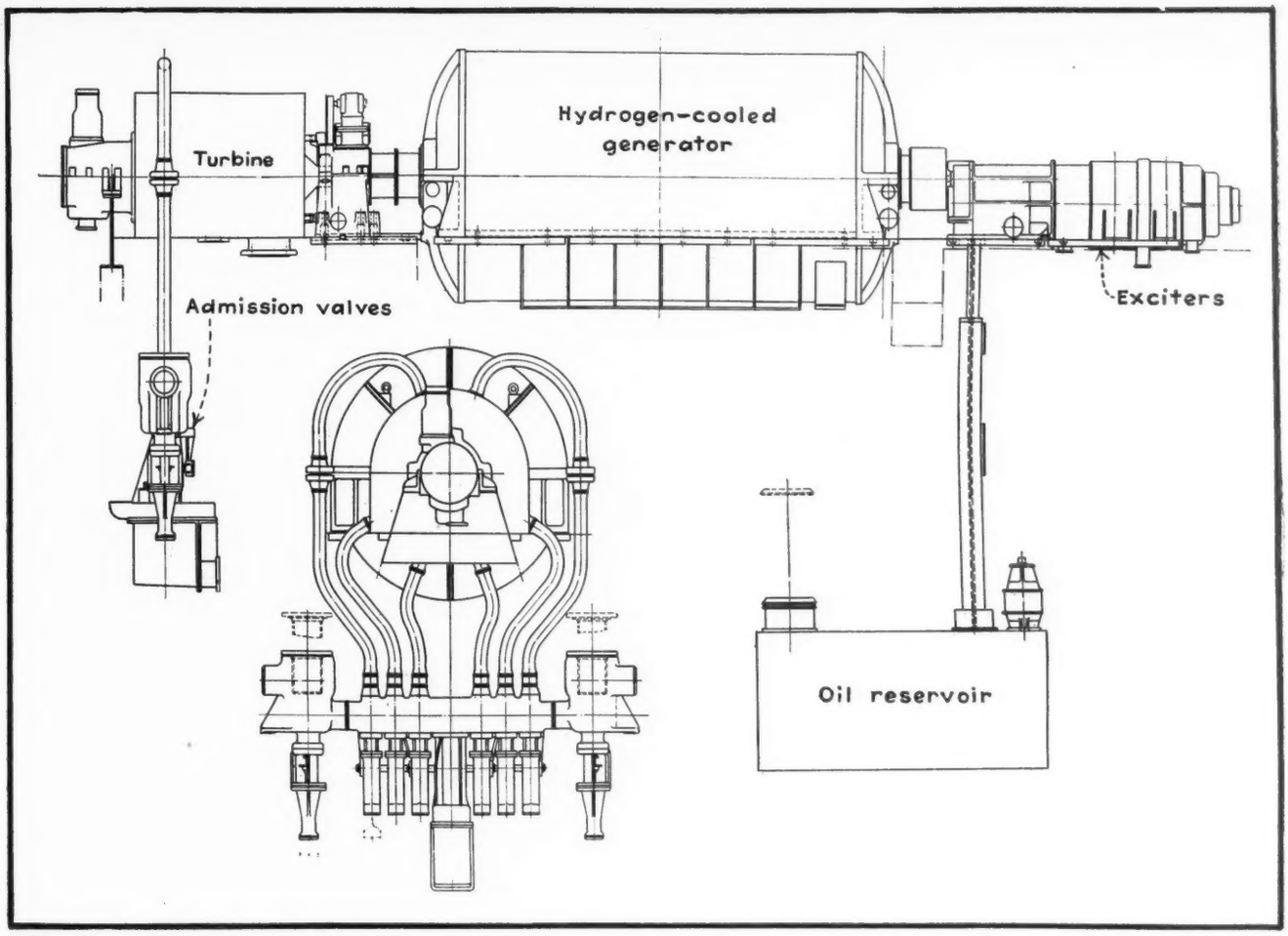


Fig. 2—Front and side elevations of the turbine and generator

kw., 0.8 power factor, and the machine nozzled to carry 45,000 kw. when extracting steam for feedwater heating and operating at an improved power factor. Combined capacity of low-pressure units was only 50,000 kw., requiring the unprecedented superposition of a high-pressure turbine with approximately 90% low-pressure-turbine capacity. It was accomplished by making some modifications in low-pressure units, driving all principal auxiliaries by low-pressure turbines supplied with exhaust from the high-pressure unit and exhausting into feedwater heater from the exhaust of the superposed turbine.

Analysis of the heat consumption indicated that the 90% increase in capacity could be attained with only 3% increase in fuel consumption. This includes the increased efficiency of the new boilers, and assumes no increase in heat rejected to the condensers.

Turbine Design

Of the three turbine designs developed, the double-shell design was chosen as best suited to meet the Logan requirements; it gave a safe and conservative solution, and permitted greatest flexibility in design. It could be built for maximum possible efficiency, and with a horizontal bolting flange that would impose no new problems in erection and dismantling.

Although this design was developed for 1,000°F., when the first 900 to 925° F. turbines were under considera-

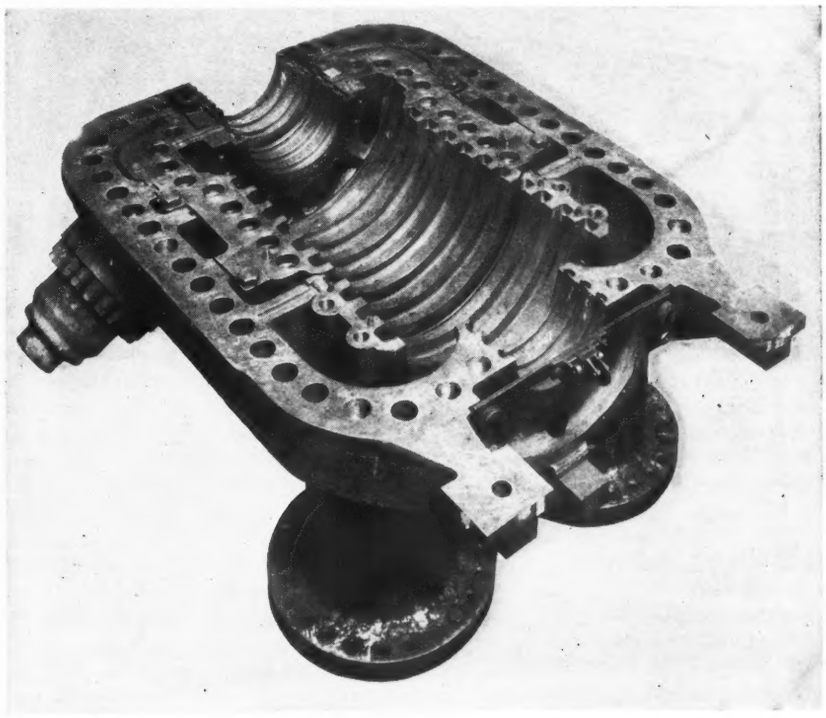


Fig. 3—Inner and outer lower half shells assembled

tion, it was decided to design the larger of the superposed 3,600-r.p.m. machines with this construction. This decision was made partly to secure greater factor of safety in initial machines for these conditions; and second, to obtain experience in actual service with this construction, so that if it demonstrated the anticipated advantages, we would be in a position to carry it out for higher steam conditions.

The term "double shell," used here, should not be confused with the 2-casing compound turbines in which expansion is divided between two separate turbines, either on the same shaft or driving separate generators, nor should it be confused with the term "double-flow" referring to exhaust casings of condensing turbines where the steam divides and flows in opposite directions in its final stages of expansion. It is used here to mean a turbine containing an inner and an outer concentric shell in which each shell carries a portion of the internal pressure. Fig. 4 shows this arrangement in principle. The turbine rotor is in the center operating at or near full steam-line pressure and temperature. The inner casing surrounds this operating portion and is in turn surrounded by a second shell, each having its own bolting flange at the horizontal joint. The space between shells is filled with steam at a pressure and temperature intermediate between that of the atmosphere and conditions in the operating portion of the turbine.

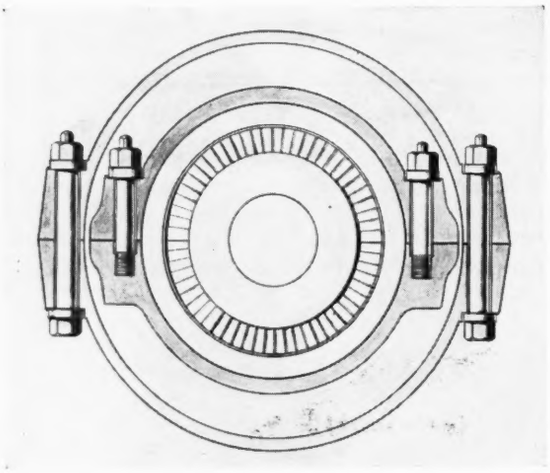


Fig. 4—Double-shell turbine

Fig. 1 shows transverse and longitudinal cross-sections of the Logan turbine in which the above principle is embodied. The inner shell surrounds the first 7 stages, and leak-off from the first section of the high-pressure packing flows radially outward, then back along the outside of the inner shell, and is returned to the turbine at the 7th stage. Seventh-stage pressure, therefore, determines the pressure that will exist between the two shells at any given load. Sealing steam from the intermediate leak-off of the high-pressure packing is at approximately 1st-stage shell-heat content, but at a lower pressure and, therefore, at somewhat less than the initial temperature, depending upon the load at which the machine is operating. The inner shell is supported by radial keys at the vertical and horizontal center lines at both ends, and located axially in line with the 1st-stage wheel. It is, therefore, free to expand in all directions, but must remain co-axial with the outer shell, which in turn is maintained co-axial with the bearings on either end of the turbine casing. Fig. 3 shows the horizontal flanges and the method of support for the inner shell.

The shell supporting the last four stages is of conventional inner-shell construction in turbines of this type for several years. It is inserted primarily to simplify the outer shell casting.

In the Logan machine, and several others which have been built, controlling valves have been arranged in a separate casing underneath the turbine. Six in number, they are connected to the several nozzle chambers by short individual pipes which enter the turbine radially, pass through the outer shell, and are connected to the inner shell by a flexible or sliding connection. These are in Figs. 1 and 2.

The joints where these pipes bolt onto the outer shell are subjected only to the pressure between the inner and outer shells. Tests indicate that internal leakage through the flexible or sliding joints is negligible.

Fig. 5—Inner shell lower half (rough machined)

In this case, the inverted position of the controlling valves not only simplifies the piping arrangement, but permits the entire valve operating mechanism to be put below the steam chest, thus keeping it cooler than it would otherwise be.

Fig. 2 shows the outline of the turbine and generator, and the unusual arrangement of the exciter, lubricating and hydraulic-oil pumps, oil tank, and controlling mechanism. It was desired to have the exciter, driven by the superposed turbine, serve not only its own generator, but also excite the generators of the low-pressure turbines. For this reason it became necessary to drive two exciters of rather large capacity at 1,200 r.p.m. This was accomplished through a high-speed helical reduction gear and advantage was taken of this arrangement to drive the main oil pumps by a worm gear from the 1,200-r.p.m. shaft. This permitted the oil tank to be put under the generator, completely away from any of the hot steam pipes. The hydraulic system is made fireproof by enclosing the hydraulic mechanism in an oil-tight steel tank connected to the drain system and locating it below the valve steam chest. The

lubrication system is protected against fire by running all bearing oil-feed lines inside of the corresponding bearing drain line.

There are a number of outstanding advantages of the double-shell construction, among which might be mentioned: simpler and more symmetrical shell castings, thinner shell walls and flanges, faster and more symmetrical heating, less internal strains during the heating period, and less possibility of flange leakage.

Fig. 5 shows half the inner shell, and illustrates the simplicity and symmetry of the castings together with the moderate thickness and width of the flanges.

One of the anticipated problems involved in designing turbines for higher temperatures results from the increasing thickness of shell walls and flanges. Reduced stresses made necessary by the increased temperature together with increasing steam pressure, have made this necessary.

Internal strains produced in the metal due to the temperature gradient during heating tend to cause permanent shell distortion. Machines of the usual type with heavy walls built for high temperature and pressure, therefore, must be heated slowly to avoid internal strains and resulting shell distortion. The time required for heating a metal wall from one side while maintaining a given allowable internal stress (resulting from the temperature gradient through the metal during heating) increases approximately as the square of the thickness.

With these things in mind, it appeared that, if required shell thickness to resist a given pressure were divided into two sections, with provisions for sharing the stress and arranged to permit the inner shell to be heated on both sides to reduce temperature gradient, it would be possible to accommodate the total thickness of metal required for the higher steam conditions, and at the same time preserve the ability to start the turbine with the greatest possible freedom from internal strain and within relatively short periods.

This is particularly significant. With modern turning gears and small-diameter solid rotors with wheels cut integral with the shaft, which constitute an extended heating surface for the rotor, the shells are becoming the limiting factor on starting time for high-pressure high-temperature turbines. Another advantage is the moderate pressure on the outer shell which practically eliminates possibility of a flange leak. Dismantling the turbine has proved no more difficult than with the usual construction.

A number of additional turbines, some for somewhat higher steam conditions and capacities, are being built along similar lines. Consideration of the possibilities opened up by this and related turbine developments makes me feel confident that successful and reliable turbines can be built for whatever higher steam pressures and temperatures may be required. Steps from this point on, however, particularly in temperature, should not be as rapid as in the immediate past, to afford an opportunity to appraise the results and to consolidate the gains of this present advance.

A-B-C of Water Conditioning

In plain English, this article sums up present-day methods of eliminating scale, corrosion, foaming and priming by proper treatment of feedwater and boiler water

By Harold E. Rose

LOCAL conditions are largely responsible for the many forms of feedwater treatment. Major losses resulting from the introduction of unsuitable feedwater are: (1) Waste of fuel (also tube damage), caused by insulating effect of scale, (2) Repair costs from corrosion of boiler tubes and shell, (3) Costs of cleaning boilers and auxiliaries, (4) Investment in additional boiler to allow for rotation while cleaning, (5) Losses from foaming, priming and wet steam, (6) Depreciation of equipment caused by scaling and corrosion, (7) Decrease in efficiency and boiler capacity.

Scale

The table lists impurities found in boiler feedwaters and the troubles they cause: chiefly priming, foaming, scale formation and corrosion. First consider scale. Boiler pressures and temperatures, plus concentration by evaporation, force solids out of solution to deposit as a hard adherent crust or scale. Salts generally responsible are the carbonates and sulphates of calcium and magnesium, and silica.

Foaming and Priming

Foaming and priming are not synonymous. Foaming is "frothing," while priming is the discharge of water with steam. Contributing causes are improper boiler design, variation in load, irregular firing, improper water composition. Boiler construction and operation have a decided influence, but feedwater composition and concentration are the chief culprits. Suspended matter, soluble compounds and organic matter aid foaming. Suspended and organic matter may be removed by filtration facilitated by the use of a coagulant. Proper blowdown control and chemical treatment will eliminate difficulties caused by concentration.

Where insufficient header capacity causes priming, carrying water at the lowest safe level will give some relief. When excessive concentration is the cause, the cure is controlled blowdown or feedwater conditioning.

Corrosion

Boiler corrosion may be a general deterioration of the boiler or localized "pitting." It is more active at higher temperatures. Influencing substances are numerous, but the following are considered principal causes of corrosion: dissolved gases, corrosive salts and electrolytic reaction.

Dissolved gases, particularly oxygen, are probably the greatest single factor in corrosion. All natural waters contain oxygen, and its introduction with feedwater starts a vicious cycle of internal corrosion, including boiler tubes, drums, superheaters, economizers and turbines. Oxygen removal completely eliminates this type of corrosion. Well-vented open heaters give good results, especially when some type of deaerator is used to remove final traces. Oxygen may be chemically removed by sodium sulphite or ferrous sulphate. The latter combines with oxygen to produce ferric hydroxide, an excellent floc to help precipitate the sludge.

Carbon dioxide enters not only as

a gas in feedwater but also as the carbonate radical of magnesium, calcium or sodium bicarbonate. When these compounds are heated they decompose to form carbonates and carbon dioxide. CO_2 in water gives "carbonic acid" which, in sufficient quantities, causes pitting. It can be removed by treating with lime or caustic soda and subsequent passage through a vented open heater.

Corrosive salts often present are calcium and magnesium nitrates and chlorides, and sodium chloride. When heated they decompose and yield free acid, very objectionable. Magnesium chloride, worst offender, reacts thus:

$$\underset{\text{magnesium chloride}}{MgCl_2} + \underset{\text{water}}{2\,H_2O} = \underset{\text{magnesium hydroxide}}{Mg(OH)_2} + \underset{\text{hydrochloric acid}}{2\,HCl}$$

The hydrochloric acid thus liberated is highly corrosive unless completely neutralized. Common salt (sodium chloride) is not actually corrosive when alone, but may easily start a vicious cycle with other compounds. With magnesium sulphate it may form magnesium chloride as follows:

$$\underset{\text{magnesium sulphate}}{MgSO_4} + \underset{\text{Sodium chloride}}{2\,NaCl} = \underset{\text{magnesium chloride}}{MgCl_2} + \underset{\text{sodium sulphate}}{Na_2SO_4}$$

Next the newly formed magnesium chloride begins to produce hydrochloric acid as previously shown, and the cycle is renewed. For effective control maintain recommended alkalinities, condition feedwater, or evaporate.

Electrolytic or galvanic action is often responsible for boiler corrosion. The cause may be the reaction between water impurities and boiler metal, or the improper grounding of nearby electrical equipment. Electrolysis liberates hydrogen and oxygen, gradually eating the metal away. Zinc plates suspended in the boiler will eliminate possible galvanic corrosion.

Table I—Common Feedwater Impurities

CHEMICAL NAME	FORMULA	EFFECT IN BOILER
Calcium carbonate	$CaCO_3$	Soft scale and sludge
Calcium bicarbonate	$Ca(HCO_3)_2$	Soft scale, liberates free CO_2
Calcium chloride	$CaCl_2$	Scale, forms $MgCl_2$ in presence of magnesium sulphate
Calcium nitrate	$Ca(NO_3)_2$	Corrosive when present in large quantities
Calcium sulphate	$CaSO_4$	Hard, dense scale, corrosive
Magnesium carbonate	$MgCO_3$	Scale, tendency toward foaming
Magnesium bicarbonate	$Mg(HCO_3)_2$	Soft scale, liberties CO_2, corrosive
Magnesium chloride	$MgCl_2$	Extremely corrosive, scale
Magnesium nitrate	$Mg(NO_3)_2$	Scale, corrosive
Magnesium sulphate	$MgSO_4$	Very corrosive especially in presence of chlorides
Sodium carbonate	Na_2CO_3	Excessive amounts produce foaming
Sodium bicarbonate	$NaHCO_3$	Liberates CO_2
Sodium chloride	$NaCl$	Foaming and priming when present in large quantities
Carbon dioxide	CO_2	Corrosion
Dissolved oxygen	O_2	Corrosive, attacks all metal auxiliaries
Silica	SiO_2	Hard, adherent scale
Oil and grease	———	Deposits, corrosion, foaming and priming
Suspended matter	———	Sludge, foaming and priming, aids in formation of soft scale

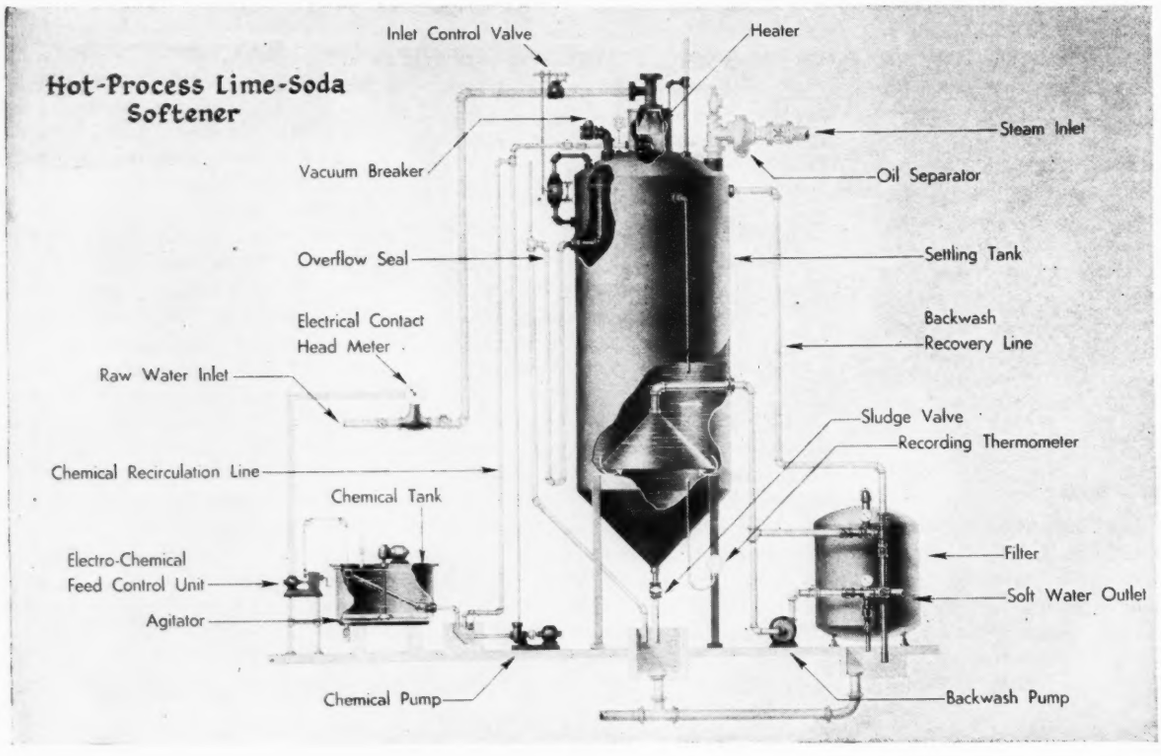
Zeolite Softening

Zeolite treatment of feedwater has gained general favor because it removes virtually all calcium and magnesium. The term "zeolite" is applied to all base-exchange silicates employed in water softening. These complex silicates will exchange their sodium bases for the calcium and magnesium bases of salts present in natural waters. The equipment is simple, consisting of a steel tank containing zeolite material on a gravel bed.

After continued use the zeolite material becomes inactive and must be reactivated by contact with a strong brine of common salt. The chlorides (introduced as sodium chloride) combine with calcium and magnesium ions and are washed out of the tank as waste, sodium ions replacing the removed calcium and magnesium. Zeolite treatment removes all calcium and magnesium, but the treated water bears sodium carbonate and bicarbonate in amounts equivalent to the carbonates and bicarbonates present in the original water. Such waters when highly concentrated in the boiler may cause foaming or priming and, under pressure, may produce sodium hydroxide and carbon dioxide. Both are objectionable as caustic soda may produce caustic embrittlement while carbon dioxide may cause corrosion. Advantages of zeolite softening include simplicity of operation, complete removal of calcium and magnesium salts, non-requirement of chemical additions, impossibility of over treatment.

Lime Process

Hydrated ("slaked") lime is probably the least expensive of reacting agents, and processing may be conducted at normal temperatures. Treatment removes calcium and magnesium bicarbonate and carbonic acid by conversion into insoluble carbonates, as follows:



$$H_2CO_3 + Ca(OH)_2 = CaCO_3 + 2\,H_2O$$
carbonic acid — lime water — calcium mono-carbonate — water

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2\,CaCO_3 + 2\,H_2O$$
calcium bicarbonate — lime water — calcium mono-carbonate — water

$$Mg(HCO_3)_2 + Ca(OH)_2 = 2\,CaCo_3 + Mg(OH)_2 + 2\,H_2O$$
magnesium bicarbonate — lime water — calcium mono-carbonate — magnesium hydroxide — water

Soda Process

The soda process is used to remove calcium and magnesium sulphate. Soda ash (sodium carbonate), either alone or in combination with caustic soda, decomposes sulphate compounds to precipitate calcium and magnesium carbonates. The newly formed sodium sulphate remains in solution and passes into the boiler. Caustic soda speeds the action; it unites with carbonic acid to form soluble sodium carbonate. The reactions follow:

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$
calcium sulphate — sodium carbonate — calc. mono-carbonate — sodium sulphate

$$MgSO_4 + Na_2CO_3 = MgCO_3 + Na_2SO_4$$
magnesium sulphate — sodium carbonate — mag. mono-carbonate — sodium sulphate

$$CO_2 + 2\,NaOH = Na_2CO_3 + H_2O$$
carbon dioxide — sodium hydroxide — sodium carbonate — water

Lime-Soda Process

The lime-soda process, a combination of the lime process and the soda processes, is the most widely used. Softeners of this type were designed primarily to treat natural water containing calcium and magnesium sulphate in combination with appreciable amounts of bicarbonates and carbonic acid, the latter under such conditions prohibiting efficient reaction by soda ash alone. After enough soda ash is introduced to decompose sulphates, lime is added to precipitate bicarbonates and carbonic acid not removed by the soda ash reaction. Successful operation requires close control and accurate analysis of incoming raw water for calculating the amount of soda ash and lime needed. After treatment the water is again analyzed to determine any excess of reacting materials so that necessary adjustments can be made.

Lime-Zeolite Process

The lime-zeolite process combines the zeolite and lime processes and is designed for the treatment of feedwater containing excessive amounts of calcium and magnesium bicarbonates. Operation consists of lime softening (to remove bicarbonates), settling, filtration through sand, and finally passing through zeolite to remove calcium and magnesium. This produces a feedwater practically free of calcium and magnesium bicarbonate, free of carbon, organic matter and turbidity, with foaming, priming and embrittlement factors materially reduced.

Internal Treatment

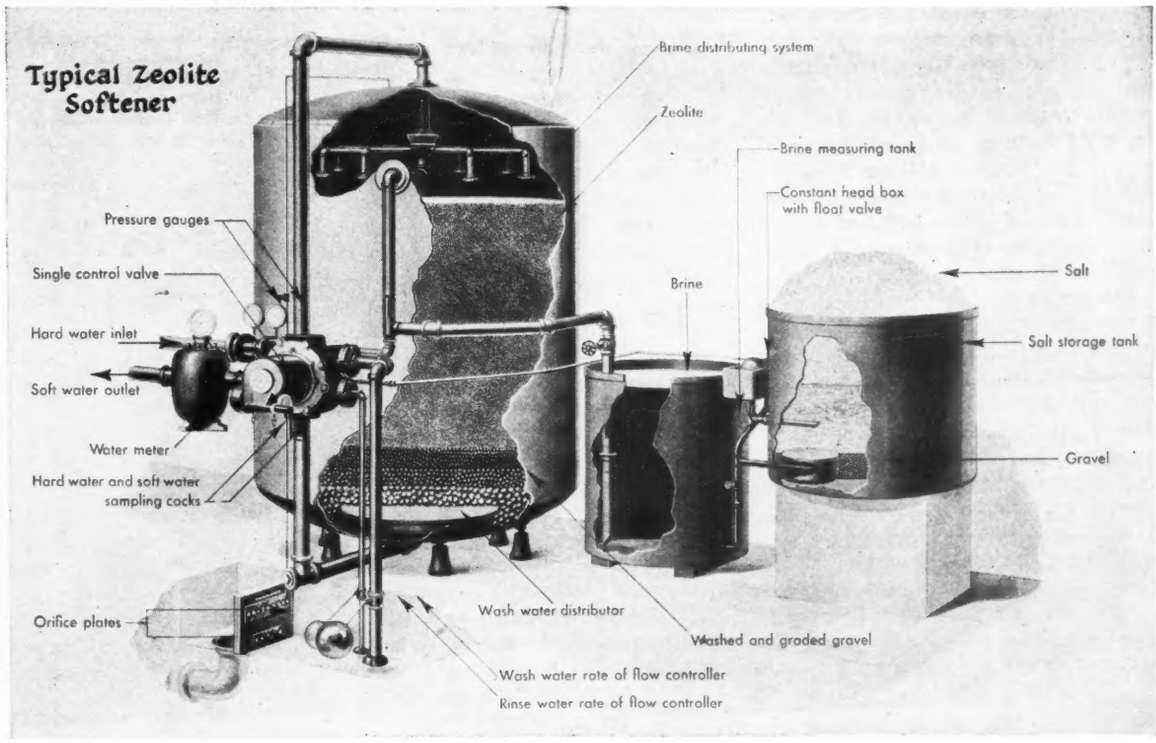
Internal treatment means introducing treating reagents directly into the boiler to prevent or control scale foaming priming and internal corrosion. Many "boiler compounds" are available but their indiscriminate use should be condemned. Some have little effect; others are detrimental and may cause serious damage but those prepared by reputable manufacturers upon scientific principles are useful and find value as water conditioning agents. In general, boiler compounds may be divided into three classes:

(1) Compounds using softening reagents (such as soda ash, caustic soda, tri-sodium phosphate, etc.) to reduce hardness. These salts, properly controlled, will prevent the formation of hard, dense incrustations, as any sulphate hardness is converted into carbonate and then removed by blowdown. On the other hand, the caustic alkalis, unless controlled, provide a composition favorable to caustic embrittlement.

(2) Compounds using tube-coating materials, such as graphite, clay talc, etc., to form a coating or film to which scale will not adhere. Such treatment raises questions regarding non-uniform distribution and injurious heat-insulating effects.

(3) Compounds of supposed mechanical action, as tannin compounds, molasses, starch, etc., whose purpose is to mix with scale-forming substances and prevent a cementing action. These are known as colloidal compounds and their functioning is based upon scientific facts. They inhibit the formation of hard, dense scale by producing a gelatinous sludge which may be removed by blow down.

The application of sodium aluminate for internal treatment is a recent innovation. Effects include the coagulation and precipitation of incrusting materials. Precipitates of this salt are very flocculent and absorb the fine particles of calcium and magnesium sulphate, silicate, suspended matter, etc. Sodium aluminate is well adapted to internal treatment as the solubility of this salt is increased by an increase in alkalinity, a condition prevalent in boiler waters.



Minus 128 Deg. Mechanically

Nobody knew what to expect with an automatic refrigerating plant cooling a product to such a low temperature. Here's what happened

By John J. Mayer
Consulting Engineer

A CLIENT in the metropolitan area was considering equipment to obtain approximately —125 deg. F. for research work in one of its laboratories. A discussion arose as to the merits of liquid air or liquid nitrogen versus mechanical equipment. Liquid air and nitrogen were rejected in favor of mechanical equipment, mainly because of control difficulty, lack of flexibility and cost of operation.

Specified duty was 4,000 B.t.u. per hr. of refrigeration at a temperature of —128 deg. F. The plant was to be as automatic as possible, it was to have an adjustable operating range from —70 to —128 deg., and it was to stay anywhere in the range within reasonably few degrees of its setting.

Many problems were present, along with much theory and little or no actual experience in the application of mechanical equipment for these low temperatures. Therefore, several surprises were in store.

Ethane (C_2H_6) was selected as the refrigerant, for it has a boiling point at atmospheric pressure of —128 deg. The next step was to obtain all the characteristics of the gas to permit proper design of equipment. Two undesirable features of ethane were its critical temperature of plus 92 deg., and that estimates, based on available data, indicated 3.2 to 97% of air in the gas at 300 lb. pressure forms an explosive mixture.

Temperature of water available for the condensers ran high, and as the critical temperature of the gas is 92 deg., the factor of safety was too small to operate an ethane system and depend on water for a condensing medium. This meant two refrigerating systems, the ethane to cool the product and another refrigerating system to condense the ethane.

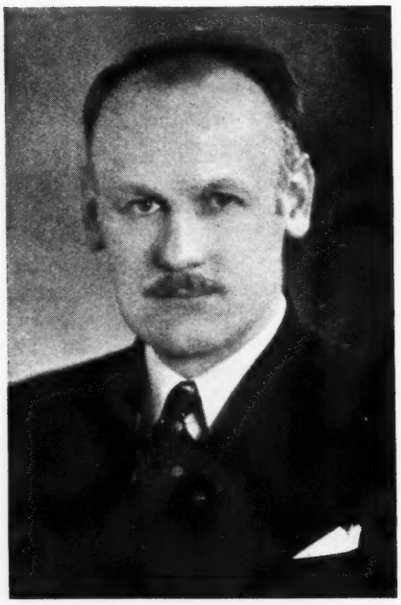
Propane was selected as the refrigerant to condense the ethane, in place of water. Many other refrigerants could have been used for this purpose, but propane at a suction pressure of a few inches of water above atmospheric gives a low-side temperature of —42 deg. for condensing the ethane. Operation of the propane system on a few inches of water above atmospheric eliminates the possibility of an explosive air-propane mixture.

At —42 deg., the condensing pressure of ethane is 120 to a possible 220 lb. pressure, depending upon the amount of superheat, provided all the ethane equipment is kept in a cold room. By keeping the ethane equipment in a cold room and the pressure below 250 lb., a standard inclosed-crankcase ammonia compressor could be used safely, and only a few minor alterations would be required to adapt it to this work.

The cold room built is insulated with 12-in. of sheet cork, applied in three 4-in. layers, joints lapped and sealed with mastic. The whole inside is finished with mastic and provided with a wooden floor. The outside is covered with sheet iron, fastened to a steel framing. Inside, the room measures 7 ft. long, 4 ft. wide, and 6 ft. high. At one end of the cold room, a sheet-iron lean-to houses the motor and drive. An airtight stuffing box in the lean-to wall accommodates the driveshaft, which is connected inside the cold room to the compressor crankshaft by an explosion-proof coupling. The driveshaft inside the lean-to is supported on ball bearings mounted on pillar blocks, and provided with a grooved flywheel. V-belts connect the flywheel with a 5-hp. explosion-proof motor. Lights in the cold room are explosion-proof and operated from outside by explosion-proof switches.

A standard 2-ton inclosed-crankcase ammonia compressor, with necessary alterations made, is installed in the cold room, along with suitable condenser and receiver.

It became apparent at the outset that a careful selection of metals had to be made to eliminate the possibility of fracture due to the low temperature. Five different copper alloys are used for parts of the system subjected to temperatures colder than —50 deg. As the compressor is made of cast iron, it was necessary that a superheater of some kind be used to warm up the ethane so it would not enter the compressor colder than —50 deg. For this purpose a heat exchanger, consisting of a ½-in. tube inside a 2-in. tube, is arranged so the warmer liquid



JOHN J. MAYER was literally born into the refrigeration industry. It all started with his great-great-uncle, Dr. Robert Mayer, whose statue is in the Hall of Fame in the Deutsche Museum, Munich, and is said to have developed the first refrigeration compressor. Since then the Mayer family have been refrigerating engineers.

John graduated from public school, but received his technical education from private tutors and from what might be called a family apprenticeship. His first job was with his father's firm, the Mayer Ice Machine & Refrigeration Co. After 3 years of service there, he went to the coast with the L. A. Ice & Cold Storage Co. Coming east in 1922 he worked again with the Mayer company, then with the Buffalo Refrigeration Machine Co., and later with the New York Carbondale Co.

Since 1925, he and his brother Albert have been together as refrigerating engineers under the firm name of Mayer.

In his spare time, John is an airplane enthusiast, student pilot and member of an aviation club. He is still an enthusiast, although his first solo flight nearly ended in disaster. His plane landed in 6-ft. high meadow grass, but luckily suffered no damage other than a temporary covering of grass and cat-tails.

ethane circulating in the ½-in. tube gives up a part of its sensible heat to the cold ethane gas in the outer tube. The heat exchanger is in the cold room and partly insulated, so the liquid ethane to the cooling unit would be as cold as possible, yet warm up the gas sufficiently to prevent shattering the compressor.

Load on the cooling unit was to be spasmodic, therefore a low-pressure float valve was built to keep a specific ethane liquid level regardless of load. The liquid gives a more positive heat transfer and accepts the load surge without a temperature change in the cooling unit.

Temperature Control

Accurate temperature control may be obtained by controlling cooling-unit pressure, hence a diaphragm back pressure valve is used for this purpose, made of bronze and sensitive to approximately ¼-lb. pressure and adjustable from atmospheric pressure to approximately 150 lb., allowing for a large adjustable temperature range in the cooling unit.

Because of the explosive characteristics of ethane, a vacuum in the system is considered dangerous. With a back-pressure valve at the cooling unit to regulate its pressure, there may be times at low load when a vacuum is pumped between this backpressure valve and the compressor. To prevent this, a diaphragm valve similar to the backpressure valve is installed between the discharge and suction lines of the compressor and set for ¼-lb. gage pressure. Whenever load is light, this valve opens, bypassing to the suction line sufficient gas to keep the pressure at ¼ lb. When load supplies a pressure above ¼ lb., this bypass valve closes.

All safety pop valves on the ethane system are set for 300 lb., and the outlets brought out of the cold room and into a large bottle of water. A glance at the bottle shows if any safety has blown or is leaking.

A thermostatic expansion valve is installed in the line that supplies liquid propane to the ethane condensers and jacket of the compressor. As equipment in the cold room is cooled by propane, it is necessary to add only a small propane coil in series with the condenser to keep the room cold.

The first surprise came with the lubricating oil. The problem of lubrication was not given much thought while planning the installation, as a general impression existed that any good grade of light ice-machine oil would do the job without difficulty. This proved erroneous.

Oil samples were received from several oil companies, and along with the samples a wide variety of ideas as to what would and what would not do the job. These samples were reduced in temperature to approximately the condition expected in the crankcase. Some with pour points much lower than the temperatures required became like petroleum jelly at as high as +15 deg. The best sample out of eight or ten tested was a light ice-machine oil, and it crystallized at —15 deg. (a splash temperature of —40 deg. was necessary). When 25% kerosene was added to the light ice-machine oil, it crystallized at —30 deg. 50% kerosene was added to the same oil and it then crystallized at —60 deg. and splashed at approximately —40 deg. However, with 50 or even 25% kerosene, the oil lost so much of its lubricating qualities that it could not be used for our purpose.

Transformer Oil

During these experiments one of the major oil companies sent several samples of its lightest and highest refined transformer oil. The lightest sample of this transformer oil, when tested, splashed at —25 deg., crystallizing at approximately —40 deg. With a small percentage of kerosene, not enough to hurt the lubricating qualities of the oil, it splashed at —40 deg., and crystallized at approximately —60 deg. This oil is used and has proved satisfactory.

Through these experiments, one thing became decidedly apparent: the pour point of a lubricating oil is of little value when a lubricant is to be selected to operate in cold temperatures. Some of the oils had a pour point 10 to 15 deg. colder than the splash; others had as much as 50 deg. and more between the pour and splash points.

As the compressor is in the cold room on the roof of the laboratory, it can neither been seen nor heard, therefore all gages and controls are installed in the main control room of the laboratory. There is a low-pressure gage to indicate pressure in the cooling unit, a low-pressure gage to indicate pressure in the suction line between cooling unit and compressor, a high-pressure gage to indicate discharge pressure, a high-pressure gage to indicate pressure in the crankcase, and a high-pressure cutout with visible settings. This high-pressure cutout contains mercury switches to shut off the compressor should the pressure go above the setting, and to ring a gong. The gong sounds due to high-pressure whether the machine is running or stopped. In a convenient location on the control board is a pushbutton to start and stop the compressor. Along with the other controls, there are several recording and one indicating potentiometers. One of the recording potentiometers records temperature at seven points every 2 min.

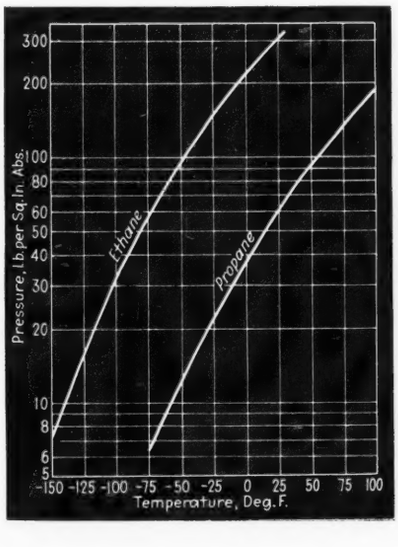
Ethane System

The complete ethane system was thoroughly tested with nitrogen gas to a pressure of 275 lb. After the leaks were fixed, nitrogen was again built up in the system to the same pressure, and the compressor run to circulate the gas. It was then blown out and another charge put in and allowed to stand for 24 hr. The room was closed and the propane system turned on to cool the room and machine. At the end of the 24-hr. period, the nitrogen was blown out, but a vacuum to evacuate all the nitrogen was not pumped on the system. A cylinder of liquid ethane was connected and allowed to flow in with the machine running, at a rate slow enough to allow the condenser to liquefy the ethane. Approximately 50 lb. of liquid ethane was put into the system, rough adjustments made on the automatic equipment, and the compressor shut down until the next day.

The compressor was started, a load put on the cooling unit and potentiometer readings closely watched. Cooling unit temperature dropped from zero to —100 deg. in about 4 min., from —100 to —125 deg., in 15 min. The machine was left running at —125 deg.

After 3 or 4 days of continuous running, the product started to warm up. First the top, then the center, then the bottom potentiometer reading started to rise. The potentiometer readings gave a very clear picture as to what had happened—the cooling unit had pumped out. This indicated the float valve had either broken, plugged or stuck closed. When the float valve was taken out and inspected, it was found not to be broken or plugged

Boiling points of ethane and propane



and showed no indication of sticking while on the bench. After cleaning and reinstalling, the equipment was again started. A discussion arose as to the possibility of moisture or oil freezing in the valve while in operation. The moisture angle was discarded as impossible, but oil in the gas was investigated and the manufacturers of the gas claimed it was also impossible. It was decided to install an aluminum-oxide dryer to absorb any moisture or oil that may be in the system, should the same trouble present itself again. This trouble did arise again, the dryer was installed, and eliminated the trouble entirely.

The system is completely automatic and operates 6 to 8 weeks, 24 hr. a day, without shutdown, depending on the type of work. It has been in use for the past 9 months. It is interesting to look at the recorded temperatures, particularly of the cooling unit. There are runs from —90 to —126 deg. recorded. Most of these runs show a recorded temperature not more than 1 or 2 deg. from the setting.

Results

Results obtained with this equipment are approximately one hundred times less expensive than they would have been with liquid nitrogen. To extract the 4,000 B.t.u. from the product, approximate power consumption is 7.5 kw. per hr.

Typical Temperature Readings, Deg. F.

Bottom of cooling unit	—125
Center of cooling unit	—125
Top of cooling unit	—100
Vapor into heat exchanger	—90
Vapor out of heat exchanger	—50
Liquid into heat exchanger	—40
Liquid out of heat exchanger	—85
Discharge away from bypass valve	Zero
Discharge near bypass	+60
Oil crankcase temperature	—20
Propane temperature	—40
Room temperature	—20

Four Fan Speeds With Two Motors

Two constant-speed motors driving through a special differential-planetary-gear unit permit four different forced-draft fan speeds to be obtained under pushbutton control

MANY ARRANGEMENTS have been developed and used for obtaining a change in speed when alternating-current motors are used on drive fans. These include constant-speed motors with hydraulic couplings or other adjustable-speed devices, wound-rotor and commutator-type polyphase motors, multiple-speed motors, two motors operating at different speeds, and other schemes. At the Laclede Gas & Electric Co.'s plant, St. Louis, Mo., an unusual multiple-speed drive, built by the Universal Gear Corp., has been selected to drive the forced-draft fans.

Differential-Gear

As shown in Fig. 1, two constant-speed motors drive a special differential-gear reduction unit that gives four different output speeds without gear shifting, all under pushbutton control. The two motors are of the simple squirrel-cage type rated at 150 and 50 hp. respectively at 1,750 r.p.m. If the small motor is operated alone, an output speed of 250 r.p.m. is obtained; with the large motor the output speed is 750. When the two motors are run in opposite directions the output speed is the difference between 750 and 250, or 500 r.p.m., and the motors are run in the same direction the output speed is 750 + 250, or 1,000 r.p.m.

The differential-gear unit may be arranged for almost any combination of four speeds, but in this case these four were selected as best suited to the fan requirements. With multi-speed motors, a greater number of speeds are obtainable. With adjustable-speed motors having 4 to 1 speed control, the output speed of the gear unit can be regulated in infinite increments from zero up to slightly less than maximum motor speed.

The gear unit is a modified planetary design with the small motor driving the planetary pinion or sun gear, Fig. 2, and the large motor drives the ring gear, one shaft being inside the other. The small motor is connected directly to the sun gear through the inside shaft, and the large motor connects to the ring gear by a multiple V-belt running on a V-grooved pulley keyed to the outside shaft.

How this equipment operates will be understood by referring to Figs. 2 to 5. In these figures the gears are drawn to a scale that gives a speed ratio of 1 to 7 between the sun gear

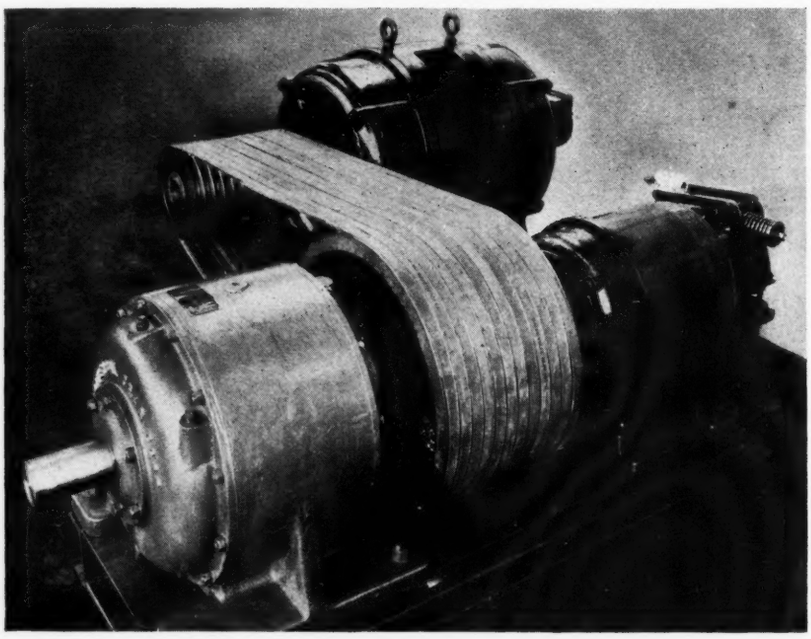


Fig. 1.—Two squirrel-cage motors connected to a special differential-planetary-gear unit for driving a forced-draft fan.

on the input shaft and the planet gears to which the output shaft connects. Because the planet gears travel around the sun gear in the same direction as it rotates, the gear ratio between the sun and the ring gear is one less than the speed ratio or, in this case, 1 to 6. With the ring gear fixed and a speed ratio between the sun and planet gears of 1 to 7, the latter will rotate at 1,750 ÷ 7 = 250 r.p.m., the output-shaft speed.

Now if the sun gear is fixed and the ring gear is rotated in a clockwise direction, as in Fig. 3, the planet gears will rotate about the sun gear in the same direction. While the planet gears are rotating about the sun gear in a clockwise direction, they have a counter-clockwise movement on the ring gear. In other words, although the planet and ring gears rotate in a clockwise direction, the former rotates at a slower speed than the latter. The relation between their speeds is such that ring-gear speed equals planet-gear speed times the speed ratio divided by the gear ratio. In this case the speed ratio is 7 and the gear ratio is 6. Then, if an output shaft speed of 500 r.p.m. is required, the ring gear must operate at a speed of 750 x 7 ÷ 6 = 875 r.p.m., which is the ring gear speed for the unit under discussion. To obtain this speed, the multiple V-belt has a speed ratio of 2 to 1, 1,750 to 875 r.p.m.

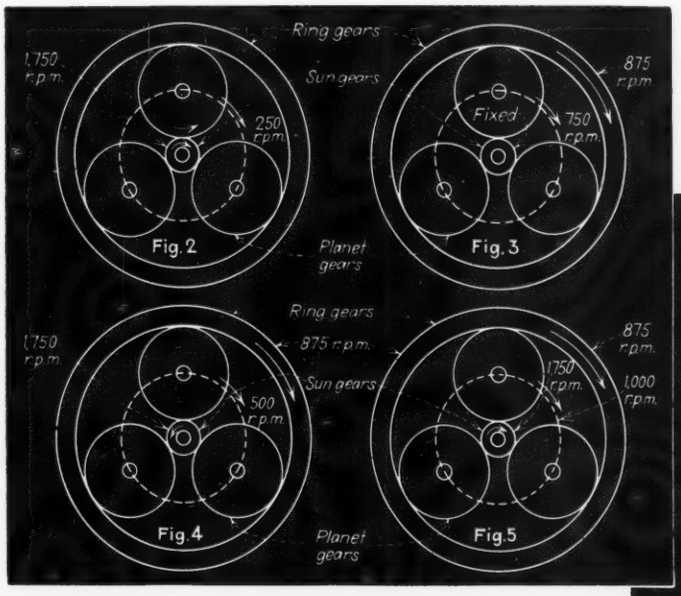
Resultant Speed

If the sun and the ring gears are both driven, the output speed of the planet gears will be a resultant speed of the two motions. For example, when the sun and ring gears are run in opposite directions, as in Fig. 4, the output speed will be the difference between the speeds obtained in Figs. 2 and 3, or 750 — 250 = 500 r.p.m. Running the sun and ring gears in the same direction, Fig. 5, will give an output speed from the planet gears equal to the sum of the two speeds obtained in Figs. 2 and 3, or 750 + 250 = 1,000 r.p.m.

Speed Curves

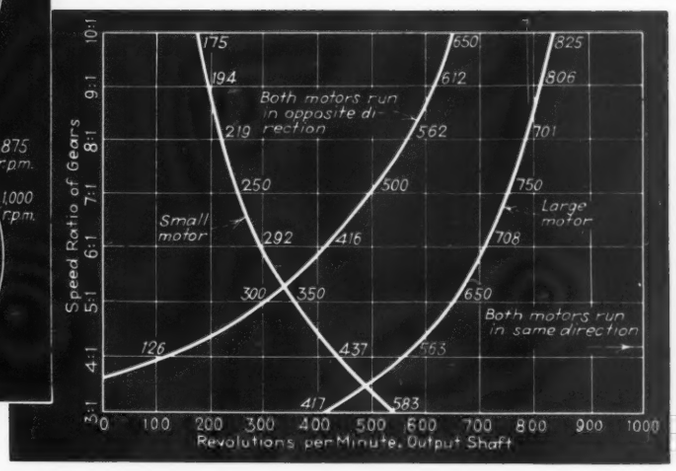
The curves, Fig. 6, show the different combinations of output speeds that may be had with different ratio gears and input speeds of 1,750 and 875 r.p.m. For gears having a 7-to-1 speed ratio, the output speeds are as already shown, 250, 500, 750 and 1,000 r.p.m. A change in gear ratio affects only the three lower output speeds, the top speed always remaining the same, 1,000 r.p.m. The only way the latter can be changed is to change at least one of the input speeds. For example, if the input speed for the large motor were made 1,000 r.p.m. then output speeds would be 1,250, 1,000, 750 and 250 r.p.m.

If we stick to 1,750-r.p.m. motors but select a top speed other than 1,000 r.p.m. by changing the input speed to the ring gear, the speed curve for the small motor remains the same as in Fig. 6, but the other moves to the right or left proportionately with the change in the top speed. For example, if the top speed is increased to 1,200 r.p.m., the two curves representing the speed for the motors operating together will move to the right 200 r.p.m. By proper selection of input speeds and gear ratio an almost infinite number of combinations of four output speeds are possible.



Figs. 2 to 5.—How four-speed combinations are obtained from the differential-planetary-gear unit of Fig. 1.

Fig. 6.—Output-speed curves for the gear unit of Fig. 1 for different gear speed ratios and a top speed of 1,000 r.p.m.



How To Paint

The following pointers are abstracted from "Paint and Varnish," Ohio State University Engrg. Station Circular No. 32: Don't start a job if the paint is chilled or the surface cold; these cause paint to thicken and "pull" under the brush. To warm chilled paint, immerse the can in water at 110 F. or let it stand in a warm room overnight.

Stir paint thoroughly before, and occasionally during, use. Dip the brush in only about one-third the length of the bristles, then tap it lightly inside the can. Don't wipe the brush on the edge of the pail—that causes air bubbles and may pick up "skin" and dirt. With ordinary flat wall paints, sweep a well-loaded brush back and forth in semi-circular strokes, smoothing out with light up and down strokes when the brush becomes lightly loaded. With rapid-drying paints like lacquers, keep the brush well loaded and apply with only one or two steady easy strokes up and down; brush marks disappear as it dries. Start painting from the top (ceilings first) and work down to avoid spattering. Remove door handles and other hardware; that's easier than painting around them. In painting sash hold a piece of sheet metal firmly against the glass to keep paint off. Hold the brush the "wide" way; a brush used sidewise soon wears to a point. Keep the brush handle about perpendicular to the surface. Brush the last few strokes of each brushful lightly from unpainted surface onto painted. When possible, paint with the grain on wood and lengthwise of other surfaces.

How to Compare Generated and Purchased Power Costs—II

This concludes the article started in May POWER which showed by examples how to compare power costs, and gives general principles and suggestions

By W. W. Gaylord
Consulting Engineer,
New Haven, Conn.

NO COMPARISON of power costs can be more accurate than the data on which it is based. Hence, for worthwhile results, cost data and operating records should be available. These data should be obtainable from the plant operation log, which should show fuel used, steam and power generated, and labor and maintenance costs.

Many small plants are not equipped with instruments to get all of these data directly, but as much as possible should be recorded. Record of fuel used can be taken from the purchase invoices if no other means is available. Total steam generated may be more difficult to estimate if no feedwater or steam flow-meter is available. It may be approximated from the fuel used and the expected efficiency of the boiler plant. H.r.t. boilers and the smaller water-tube boilers, hand-fired, may be expected to give from 63 to 65% over-all efficiency with average good operation. Stoker-fired boilers will give slightly better average efficiency if the banking periods are not unusually long. H.r.t. boilers and water-tube boilers up to 4,000 sq.ft., stoker fired, usually have an over-all efficiency of 67% to 70%.

If there is a recording wattmeter or a watthour meter, the total power generated can be taken from this, but if only indicating instruments are available a log of average loads and hours operated will give a close approximation.

Steam used by the generating equipment can be estimated from the power generated, and the steam rate given by the engine builder or that given for similar equipment found in standard handbooks. The "steam rate chart" published on page 308 and the additional data on page 313 of the June, 1936, issue of *Power* will be found useful in checking steam rates of equipment for which exact data cannot readily be found. In using these values it should be remembered they are for approximately full-load conditions and that the engine efficiency, mechanical efficiency and generator efficiency all decrease at partial loads.

Actual steam rates are found by dividing the theoretical steam rate, as determined from chart or calculated from the steam conditions, by engine efficiency, mechanical efficiency and generator efficiency for the average engine load, Table II.

Steam required for building heating is another quantity that must often be determined indirectly, as few plants meter it. If the square foot of radiation is known, heating steam can be estimated in several ways. Perhaps the most satisfactory is the degree-day method in which the degree-days for the period are multiplied by a constant for the type of heating system, to obtain the total steam used.

This constant of course varies with the type of factory or building and operation found, but the Table I values are fairly representative: this constant in each case being the pounds of steam per square foot of equivalent direct radiation installed in the plant or department per degree day.

If the square feet of radiation are not known and the square feet of floor space are, radiation can be approximated by allowing 1 sq.ft. of radiation for every 8 to 10 sq.ft. of floor space if the ceilings are not more than 12 ft. high and the windows of average size.

Degree-days for each month are now published by the Weather Bureau in most localities, but if these are not available they can readily be found by determining the amount the mean temperature of each day is below 65 deg. (if the mean temperature for a day is 45 deg., that day counts as 20 degree-days).

Process steam required or used is another quantity that is often difficult to get directly; it may have to be estimated. Where process steam is largely used to heat water it may be determined from the weight of water

Table I—Lb. Steam per Sq.Ft. of Equiv. Direct Radiation per Deg. Day

Factory operating 8 hr. a day employing only men where these men are in motion most of the time	0.050
Factory operating 8 hr. a day employing men only with mixed machine and bench work	0.065
Factory operating 8 to 10 hr. a day employing both men and women; average conditions	0.080
Factory operating 8 to 10 hr. a day employing mostly women machine operators. Also average office and commercial building	0.100
Factory heated 12 hr. a day where a majority of employees are women and work sitting down	0.110

Table II—Efficiencies

	4/4 Load	3/4 Load	1/2 Load	1/4 Load
Engine efficiency: uniflow	73	74	73	69
Engine efficiency: corliss	65	66	64	55
Engine efficiency: single-valve	56	57	53	45
Mechanical efficiency	90	87	82	70
Generator	93	92	90	85

heated per hour and the range through which it is heated. Where steam is used in coils or cylinders to heat work directly the condensate can be weighed or measured for a period, and the rate thus found used to calculate the total. If it is impossible to either weigh or measure the condensate and the surface of the coils or cylinders is known, the expected condensation can be calculated from known radiation constants which apply as nearly as possible to the particular condition.

Another point to be remembered is that when no power is generated and the boilers operated only to supply process steam, the banking losses will be as great as if power were generated.

To Use These Data

To show how these approximations can be used apply them to the first case given in the May article where the power plant contained one 2,400-sq.ft. boiler and a 200-kva. engine-driven generator.

The engine is a simple 4-valve, non-condensing type direct-connected to a generator, and handbooks show that for $\frac{1}{2}$ to $\frac{3}{4}$ load this would have a steam rate of 26 lb. per indicated horsepower when operating with steam at 120-lb. gage and 2-lb. back pressure. The mechanical efficiency of such an engine is about 90% and the generator efficiency about 92%, which makes the steam rate per kilowatt-hour $\frac{26 \times 1.34}{0.90 \times 0.92} = 42$ lb. As there were 193,400 kw.-hr. generated the steam used by the engine was 8,122,800 lb.

This factory employs men only but has considerable bench work so will take the rate of 0.065 lb. of steam per degree-day. The degree-days in this locality for 1935 were 5,863, so with 11,000 sq.ft. of radiation the steam for heating per year figures $11{,}000 \times 5{,}863 \times 0.065 = 4{,}192{,}045$ lb.

The principal use of process steam was in a plating room where steam was used to heat plating tanks, wash water, etc. While this department operated only 8 hr., it was found the steam must be put on an hour earlier to heat up the tanks, and that the steam used during this hour was more than twice as much as that used per hour after the tanks were heated. The steam was also left on the tanks over the noon hour so the total daily use was equal to about 11 hr. at the average rate after the tanks were heated. It was found that this rate was equivalent to heating 600 gal. of water per hour, an average of 140 deg. F. and therefore required about 600 lb. of steam per hour. This department operated 250 days per year so the total steam required was figured as $11 \times 250 \times 600 = 1{,}650{,}000$ lb. per year. Total steam required per year assuming no exhaust steam was used for heating was then:

Power	8,122,800
Heating	4,192,045
Process	1,650,000
Total	13,964,845 lb.

The h.r.t. hand-fired boiler is well operated and not overloaded, but having relatively long banking periods an efficiency of 62% may be expected. Coal used has a heat content of 15,000 B.t.u. per lb. and there is ample exhaust steam to heat the feedwater which enters the boiler at about 200 deg.

Evaporation per lb. of coal then is

$$\frac{15{,}000 \times 0.62}{1{,}190 - 168} = 9.1 \text{ lb.}$$

On this basis the coal used per year, if no exhaust steam were used for heating, would have been 765 tons.

Actual use was 650 tons, which shows that exhaust steam equivalent to 115 tons of coal was used in heating.

With Purchased Power

Now take the condition where power is purchased and the load on the boiler is much less. Banking losses will remain the same, so expected average boiler efficiency will drop to 60%. Operating pressure will be dropped to 50 lb. and feedwater temperature will be only 170 deg., as only the exhaust steam from the feed pump will be available for heating it. Also as there are no returns from the process steam each pound used for this will be equivalent to 1.11 lb. used in the heating system. The total equivalent steam used will then be:

Heating	4,192,045
Process $1{,}650{,}000 \times 1.11 =$	1,831,500
Total	6,023,545

While this case shows the general procedure, the details will of course have to be modified in each case to suit the equipment and method of operation.

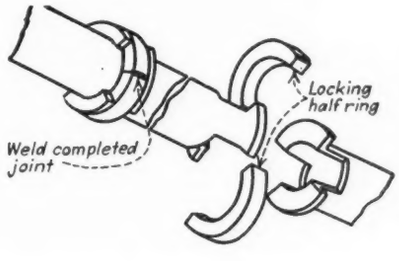
These examples show that it is necessary to consider many items other than the cost of power per kilowatt-hour delivered at the switchboard to determine whether purchased power will reduce total plant operating costs; and after all, this is what the management is interested in rather than a nominal cost per kilowatt-hour for power. Unless some analysis similar to that outlined above is made, what at first looks like a large saving may be merely transferring the cost from one division account to another in such a way that the total actually may be increased. This is particularly true where a considerable part of the estimated savings are in labor costs or fixed charges on equipment. It is frequently found, particularly in the smaller plants, that purchase of power will make no reduction in the number of men employed in the service department, and little if any change in their rates. There can be no justifiable reduction in fixed charges on the generating equipment even if it is not operated unless it can be sold and the amount received applied to reduce the capital on which the fixed charges are based.

A Fair Basis

By applying these methods a comparison can be made which will be fair to both the plant owner and the power company, and the management will be able to decide the question of purchasing power on the basis of whether or not it actually will reduce total operating costs of the plant considering a changeover.

Rings Lock Welded Joint

Former lack of confidence in the dependability of welds led designers to many protective devices. Some shifted stress from welds to non-welded metal, others, such as sleeves, added more welds for "good luck". These makeshifts are costly and often of little protective value. It is even claimed that reinforcing straps set up internal stresses that do more harm than good.



The Feb. 27 number of *Die Warme* (Berlin, Germany) pictures an ingenious mechanical arrangement for coupling pipes end to end without bolts and without appreciable stress on welds. One notched pipe is slipped over the other until there is enough space between flanges to slip in the two locking half-rings. Halves are then welded into a single ring. Obviously, much seal-welding is necessary to make the joint tight.

Safe Harbor Welding Experience—III

Two previous articles, in March and May POWER, told how the pitted areas on four 42,500-hp. turbines were welded with stainless steel. This, the concluding article, presents some conclusions as a result of the welding experience and indicates possibilities of obtaining an alloy to resist better the action of cavitation on hydraulic-turbine parts

By P. M. Hess
Station Superintendent,
Safe Harbor Water Power Corp.

TO REPAIR the more severely pitted areas on the four turbines installed in 1933, in a comparatively short low-flow season, without resorting to demand outage, required that the welding be done at more or less inconsistent locations on all the blades. During 1934, 1935 and 1936 an effort had been made to correct extended pitted areas and join the welded sections to obtain a more or less continuous stainless section. This work involved removal, in many cases, of apparently sound metal and increased the scope of the work; however, in later years this should prove beneficial.

On some of our earlier work, repairs have been found necessary on the stainless sections due to experiments with various types of rods, determining the correct depths to be chipped for weld application and local reshaping to correct curvature which in places caused the stainless layer to be too thin. It has been found that the stainless layer should be at least 1/10 in. thick. If repairs are required on pitted stainless material, it is necessary to remove this metal by grinding instead of chipping as we did on the initial work. To date no satisfactory method of chipping a stainless weld has been found, because of its extreme hardness.

For overhead welding we have found that a ⅛-in. welding rod not more than 9 in. long is most satisfactory. Longer rods were tried in an effort to reduce end losses, but developed heat-control difficulties. Even when the lowest current required to satisfactorily apply the rod (approximately 80-90 amps.) is used, the last few inches of a 12-in. rod become so hot that the deposited characteristics of the weld are changed. Current and are characteristics of the rod are different for the first half than for the latter half, making satisfactory application difficult. A 5/32 in. by 11-in. rod is used to weld the throat ring. End losses from ⅛-in. rods amount to approximately 15% from 5/32-in. rod about 12%. Tests have shown that approximately 80% of the full length of rod used is deposited in the weld, producing final finished figures of

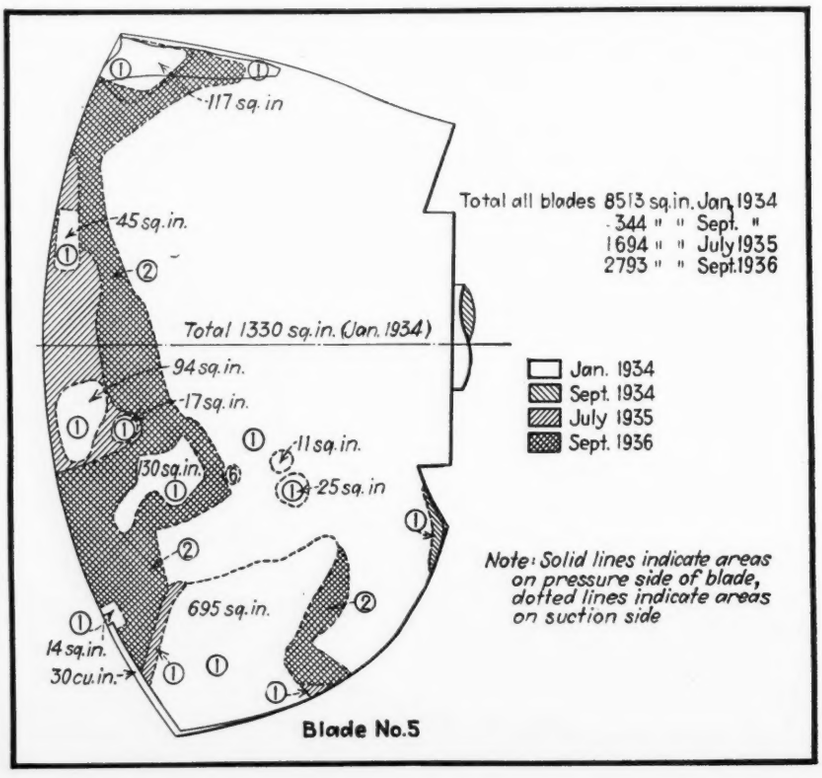

117 sq. in
45 sq. in.
Total all blades 8513 sq.in. Jan. 1934
344 " " Sept. "
1694 " " July 1935
2793 " " Sept. 1936
Total 1330 sq. in. (Jan. 1934)
94 sq. in.
17 sq. in.
11 sq. in.
130 sq. in.
25 sq. in
695 sq. in.
14 sq. in.
30 cu. in.
Jan. 1934
Sept. 1934
July 1935
Sept. 1936
Note: Solid lines indicate areas on pressure side of blade, dotted lines indicate areas on suction side
Blade No. 5

Fig. 20—Form on which a record of welding done on each blade is made.

DAILY RECORD OF METAL WELDED
Unit No. 5 Shift 12-8 Date JULY 12, 1936

Blade No.	Location	Type, Amount and Size of Welding Rod Used: Mfgr. Z 1/8"	Mfgr. Z 5/32"	Mfgr. X 1/8"	Mfgr. X 5/32"
10	C	80 RODS 18-8			
8	P			15 RODS 18 CR	25 RODS 18 CR

A-Top Leading D-Bottom Middle
B-Bottom Leading P-Periphery
C-Bottom Trailing T-Trailing
Machine Used No. 2
Hours Worked 8 Welder John Doe

Fig. 19—Form on which welders make a daily record of metal welded.

44% of metal on the blades for the 1/8-in. rod and 62% in place for the 5/32-in. rod on the throat ring. The difference between the final figure and that deposited is ground away to obtain a homogeneous finish. This final figure is variable, being controlled more or less by the technique of the chipper and welder.

Fig. 19 shows the form used by each welder to record the amount, type and size of welding rod used daily, and to designate where the rod has been applied. At definite times, a member of the Test Department measures the areas chipped on each blade and determines their average depth as nearly as possible. These figures are recorded on the form, Fig. 20, on which is added the type of welding rod applied to the chipped area, each type of rod being designated by a code number. The figure shows one blade only, but the actual form contains all five blades of the unit.

Application of stainless metals to pitted areas is not a cure-all, but is far superior and will better withstand the unceasing blows of cavitation, and in addition resist corrosion which in itself accelerates pitting.

Research

Much research work has been and is still being conducted by this company on causes and cures for pitting. Recently attention has been given to the ability of alloys, both ferrous and non-ferrous, to withstand the action of cavitation. Tests are conducted in a model in which the action of cavitation is greatly accelerated where a run of 16 hr. is sufficient for comparison. All known contributing factors are investigated, including grain structure, heat treatment, flux coatings on rods, varying carbon content, etc. A typical result curve is shown in Fig. 21, where the ability to withstand cavitation is plotted against Brinell hardness. The parent metal in the turbine blades with a Brinell of approximately 155 is considered as having a cavitation resistance factor of unity.

Stainless Steel

The stainless (18% chromium, 8% nickel) used at Safe Harbor produces a finished weld of about 240 Brinell, with a resistance factor of approximately 0.25, whereas the straight 18 chromium rod produces a finished weld of approximately 350 Brinell. These figures indicate that stainless 18-8 should have a life of at least four times the parent metal. Its life is probably much more, since the characteristic of work-hardening possessed by 18-8 will undoubtedly increase its resistance to cavitation. Variations in Brinell hardness, Fig. 21, for 18-8 rod are attributed mostly to its carbon content and carbon pick-up in the welding process. Carbon content of stainless rods is, therefore, very important.

Fig. 22 shows the action of cavitation on a stainless 18-8 welded section of a blade after two years of operation. The particular rod was found to be comparatively high in carbon. Sections at similar locations, welded with stainless 18-8 low in carbon show very little pitting. Therefore, when purchasing stainless rods, request a certificate of analysis specifying a carbon content of not more than 0.07%.

Knowing that stainless metals having a high Brinell hardness withstand the action of cavitation better and that 18% chromium rods having a very high Brinell showed up well as a test specimen, we decided to try this rod on the turbines. In 1935, an area of approximately 8 sq. ft. was welded on the turbine throat ring. This rod could be applied easier and faster than the 18-8, but the grinding operation required approximately 50% more time. After grinding, the finished surface showed many hairline cracks, an indication of low ductility caused probably by extreme hardness of the weld accentuated by rapid cooling due to heat absorption.

Further investigations showed that the weld contained an excessive amount of carbon, some attributable to the initial analysis, some to the rod coating used and perhaps some picked up from the parent metal. In 1936 an 18%-chromium rod was applied, having a lower initial carbon content and a different flux coating, with much more promising results. In addition to these trials, rods containing 12 to 15% chromium and 0.5 to 2% nickel were applied both on the blades and throat rings. As with straight chrome, hairline cracks developed in the finished weld due to too rapid cooling, and its use was temporarily abandoned. We believe, however, when a rod containing about 12% chromium and a small percentage of nickel can be properly applied without cracking, that it will be superior to the 18-8 rod we are now using.

Thieves Steal "Hot" Line

In a night raid on energized lines of Pacific Gas & Electric Co. near College City and Colusa, Calif., recently, thieves cut down three miles of 11,000-volt conductor and made a get-away with the copper. Service in the vicinity was interrupted. Apparently trucks and reels were used.

Fig. 21—Curve showing the ability of metals to withstand cavitation, compared with their Brinell hardness.

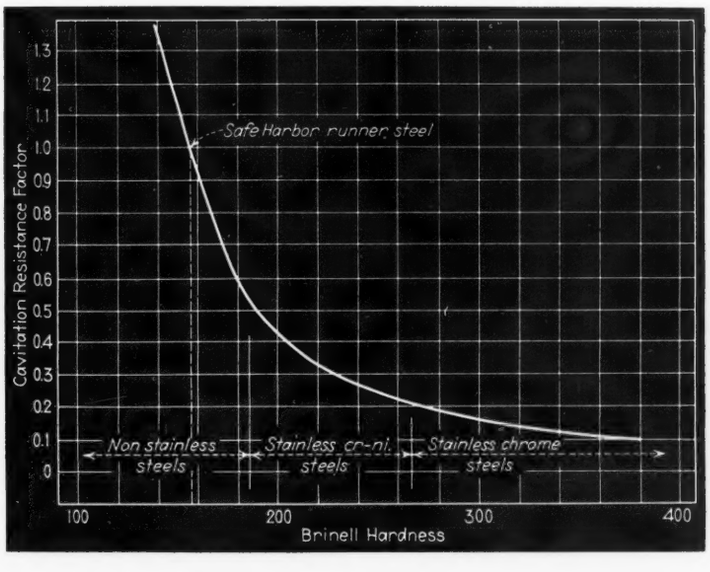
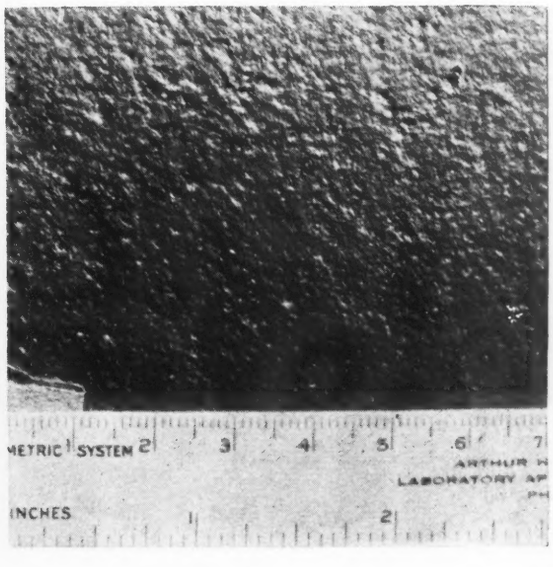


Fig. 22. — Closeup showing action of cavitation on stainless welding on a blade after two years' service.



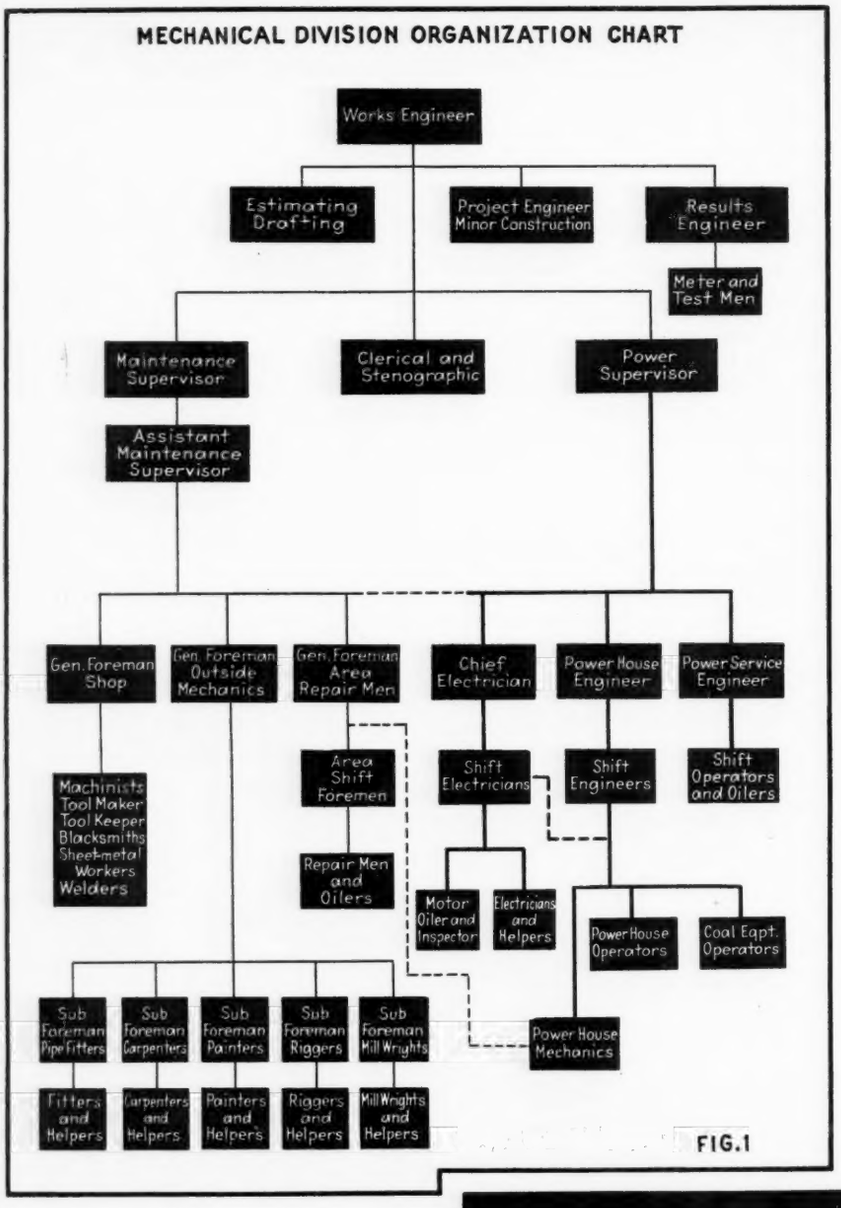


FIG.1

What Is The Power Supervisor?

Who is in charge of power in the large industrial plant? What does he do? Here are the answers to both questions

By S. H. Coleman

JUST WHERE does the power engineer—or in the larger industrial plant, the power supervisor—fit into the general organization picture? What are his responsibilities? These two questions are often answered differently for each plant. But in some general respects, position and responsibility are the same, so Figs. 1 and 2, with slight modifications, can be applied to almost any industrial organization.

The organization chart, Fig. 1, shows the supervision and personnel setup of the mechanical division of a large processing plant in which power costs are a major item of operating expense. While there is of necessity a slight overlapping of functions between the power and maintenance sections, the chart definitely points out "who is responsible to whom."

Responsibilities of the power section are shown in Fig. 2. The power supervisor and the men under him are responsible not only for the production of power services, but also for their distribution, and to a large degree for their utilization. This system works for greater efficiency and places under one control all costs incidental to these services.

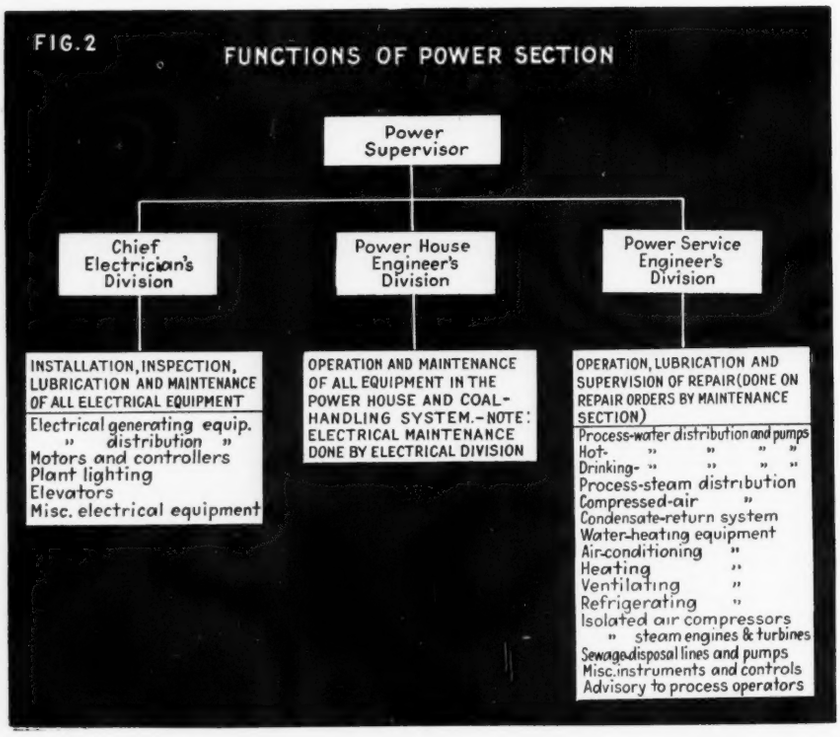


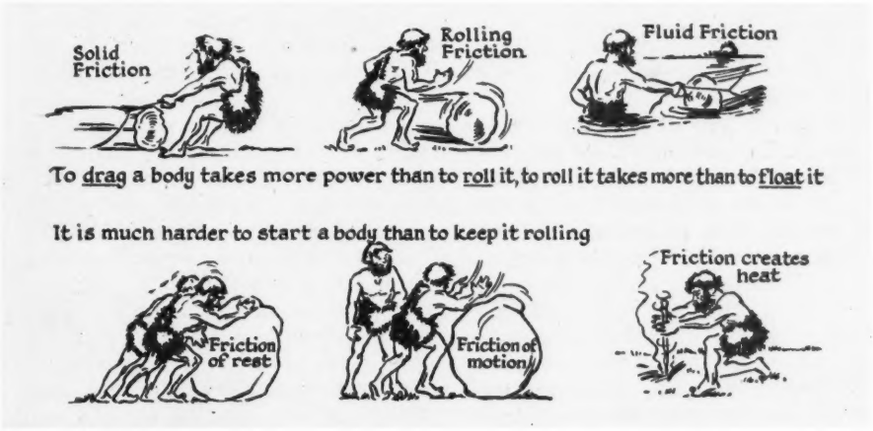
FIG.2
FUNCTIONS OF POWER SECTION
Power Supervisor
Chief Electrician's Division
Power House Engineer's Division
Power Service Engineer's Division
INSTALLATION, INSPECTION, LUBRICATION AND MAINTENANCE OF ALL ELECTRICAL EQUIPMENT
Electrical generating equip.
" distribution "
Motors and controllers
Plant lighting
Elevators
Misc. electrical equipment
OPERATION AND MAINTENANCE OF ALL EQUIPMENT IN THE POWER HOUSE AND COAL-HANDLING SYSTEM.-NOTE: ELECTRICAL MAINTENANCE DONE BY ELECTRICAL DIVISION
OPERATION, LUBRICATION AND SUPERVISION OF REPAIR (DONE ON REPAIR ORDERS BY MAINTENANCE SECTION)
Process-water distribution and pumps
Hot- " " " "
Drinking- " " " "
Process-steam distribution
Compressed-air "
Condensate-return system
Water-heating equipment
Air-conditioning "
Heating "
Ventilating "
Refrigerating "
Isolated air compressors
" steam engines & turbines
Sewage disposal lines and pumps
Misc. instruments and controls
Advisory to process operators

HOW TO BEAT FRICTION

E. J. TANGERMAN, Managing Editor

FRICTION makes it possible for a man to walk, for a belt to pull, for an automobile to move. Without it man couldn't exist. But it is also one of his greatest problems, for whenever two surfaces slide over each other, there is friction, bringing with it wear, heat, shortened life, and the need for lubrication.

The ancients first began to learn about friction when they tried to wall in their caves. A square block was difficult to push, but a round boulder rolled easily. A log that two men found almost impossible to drag or push was rolled easily by one. And when the same log was put in water, it was child's play!


Solid Friction
Rolling Friction
Fluid Friction
To drag a body takes more power than to roll it, to roll it takes more than to float it
It is much harder to start a body than to keep it rolling
Friction of rest
Friction of motion
Friction creates heat

The cavemen didn't know they had discovered one of the basic laws of friction, namely that sliding friction between solids requires most power, rolling friction less, and fluid friction least. By converting from solid to fluid, they saved power. They noticed that dragging the log along the ground made the ground warm, but they didn't understand that sliding friction produces most heat, rolling friction less, and fluid friction least of all.

Again, they found that a body difficult for two men to start could be kept moving by one—another of friction's basic laws, for we know now that friction of rest is much greater that friction of motion. And lastly, they knew that to get a fire from one of their crude bow drills, they had to keep it free of animal fats. Why? Because dry, its rotation produced sliding friction, generating the most possible heat; a little fat converted it to fluid friction and little or no heat was generated. They used that principle in greasing skids, but they didn't realize that in so doing they were heading towards modern principles and practices of lubrication.

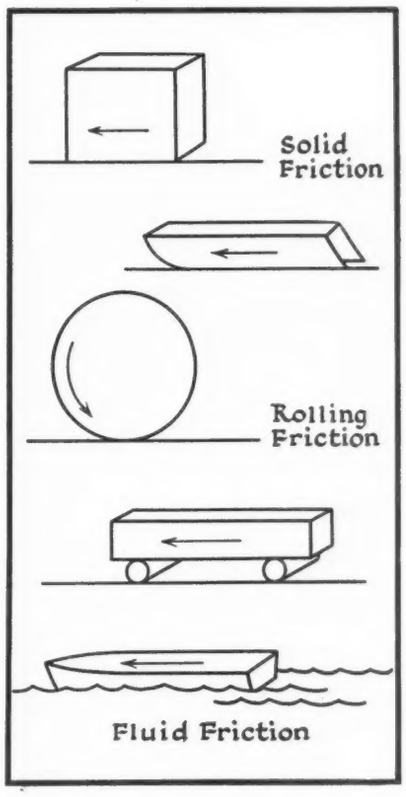
We say "modern" advisedly, because lubrication was without rhyme or reason until the past half century. Man gradually learned to grease axles and to lubricate pivots and sliding shafts, but he didn't know exactly why he did it. As he learned more about lubrication, he found that shafts could take more load, that piston clearances could be smaller, that sliding surfaces could be more accurate. It was lubrication as much as anything else that brought the Industrial Revolution, that drastic change in ways of living that gave men the conveniences of today.

As A Science

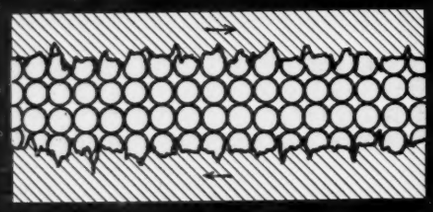
About fifty years ago, men began to study lubrication as a science, and though their progress has been slow through the intervening years, that progress has been all that has kept our modern machinery operating. As an army marches on its stomach, so does a modern machine depend upon its lubrication. Build as elaborate a machine as you wish and power it as you will, but if you can't lubricate it, you can't keep it going.

In this age of specialists, it was inevitable that there would grow up a race of "lubrication engineers". They came to look at a troublesome machine, they stroked their chins and recommended something, and the trouble disappeared. But the modern engineer, even conceding these things, wants to know why and how so that he can cooperate more intelligently. He is loath to make use of something of which he is not certain, to apply something he does not entirely understand.

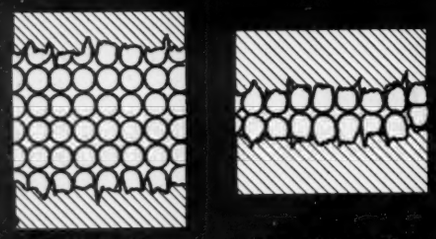
This the editors of *Power* have accepted as a task, in this 13th of our Special Sections, to put into short compass and simple words the fundamentals of lubrication, so that every operating engineer may understand them. For example, he wants to know why the cheapest oil isn't usually most economical. Ours is not the task of building lubrication engineers, but of helping men to understand what the lubrication engineer does and why he does it. By showing how correct lubrication cuts operating and maintenance costs by reducing friction and increasing heat removal, we endeavor to make the problem simpler, so that every power unit can be operated more efficiently.

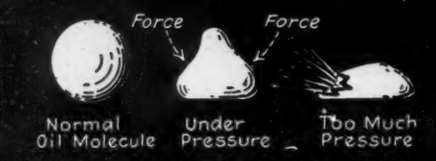


Solid Friction

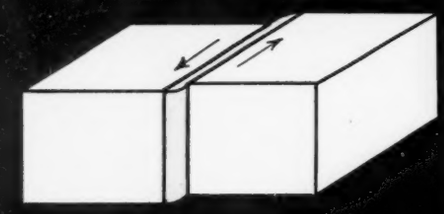


Fluid Friction

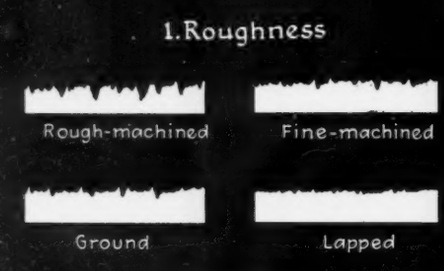




Oil Under Pressure



Fluids Stick to Solids



Two Conditions Govern Friction

What is Lubrication?

• We have already seen what friction, working against us instead of for us, can do; how solid friction varies from rolling, and rolling from fluid. But what is lubrication, and what does it have to do with all this?

No matter how carefully a surface is machined or ground, that surface is full of hills and valleys, of pits and peaks. Now take that piece of steel and rub it against another piece. Hills in one piece fit into valleys in the other, pits in one fit over peaks in the other, and the two pieces tend to "stick" together, like a pair of files with ultra-small teeth. To make one piece pass the other, we must separate them enough so that hills on one slide past those on the other, or cut down some peaks and fill up some valleys, then provide a lot of balls or rollers to avoid the sliding.

That's the only simple (though not entirely accurate) way to describe what a lubricant does. (Actually, the mechanism of lubrication is quite complex; the theory is not yet understood.) Picture several rows of infinitely small balls between the pieces. One row of balls fills the holes on one piece, one row fills those on the other, and the rows in between roll easily over one another—no jagged peaks or deep valleys now! But the balls, instead of being steel, are oil molecules.

Why does oil do this? Because of those two old friends, cohesion and adhesion. The two pieces of steel being rubbed together have a lot of cohesion, that is, the molecules of each piece like to stay together and resent being shoved around. That's true of any solid. But any body with high cohesive power usually has little adhesive power, and vice versa. Ordinary mucilage, for example, hasn't very much cohesive power, unless it's frozen, but it does right well as an adhesive. Oil is somewhat the same. It has high adhesive quality—likes to stick to steel—but low cohesive quality—doesn't mind being pushed out of shape. So the oil promptly adheres to the steel on both sides, and its molecules roll over one another like so many marbles.

Of course, it's possible to put so much pressure on those marbles that they are squeezed out at the sides or are crushed. That's where selection of a proper lubricant comes in—you simply provide a "harder" oil, one that resists deformation more, one that has a little more cohesion. And eventually you get those two steel surfaces separated by a film of fluid that floats each on the other like a boat floats on water. That's fluid friction—least wearing on the parts because less heat-and-wear-making power is required to move one over the other.

All lubrication isn't as simple as that—proper cohesive and adhesive relationships of the lubricating film and proper distribution of pressure between the rubbing bodies are only two of the factors. Sometimes, as in a diesel cylinder, there is heat to be removed. Sometimes, as in a steam cylinder, there may be moisture or water that likes to work its way between oil and steel. Sometimes, as in a machine bearing, there may be fine metal chips or other contaminants trying to work their way in. But lubricants worthy of the name can be prepared to meet any condition.

And if your problem is too difficult for you, why that's where the trained specialist pulls his share of the load. He begins a process of cutting the cloth to fit the suit—a little of an oil that has this desired quality, a little of an oil that has another desired quality. The mixture is not as good as either of its parts in that part's specialty, but it has some of the qualities of each one. By such blending of mineral oils alone, or compounding with animal or vegetable fats, your specialist produces an oil that will do your job. He produces a lubricant that will stay in place under pressure, provide the necessary molecular layers to give good "rolling" of one layer on another, and yet has the characteristics necessary to meet the special conditions of surfaces, speed, clearances and load.

Of course, the proper lubricant may not be an oil—it may be a grease or a solid lubricant, depending upon the particular set of conditions. Essentially, a grease may be considered to act just like an oil, except that it has more "body." But a solid lubricant like graphite really is a lot of tiny smooth scales that fill in the valleys, then slide over each other as smoothly as a sled runner glides over ice.

The Variables

Any lubrication job boils down to two surfaces in contact, with a lubricant in between that floats the moving body as surely as a river floats a log, whether the log is moving or still. But salt water floats a log higher than fresh, and current moves a log while still water lets it rest. Let's go on to explore the currents and still water, the fresh water and salt, that complicate the lubrication picture. First, so we're all talking the same language, we'll discuss terminology, tests and specifications and what they mean, then we'll go on to sort out the oils, fats, and soaps that may be mixed together to make a lubricant. Any sap can mix gin and ginger ale, but it takes understanding and experience to mix a cocktail that sets right—both now and tomorrow morning.

What Lubricant Tests Mean

• It isn't enough to compare two children on the basis of facial appearance —you've got to go deeper than that. So is it with lubricants.

Fundamental in any comparison is *viscosity,* the resistance offered by a fluid to flow. If a fluid hates to allow its molecules to flow one over the other, and thus to change its shape, we speak of it as viscous, or high in viscosity. Molasses is viscous. But oils, like molasses, flow easier in June than in January—heat changes their viscosity. So oils must be compared at the same temperature. Further, viscosity of one oil may change more for a given change in temperature than another. Oils, in order to have identical characteristics at operating temperature, must at least have the same viscosity *at that temperature.*

For scientific work, *absolute viscosity* is used, and is the force in dynes per square centimeter required to move a horizontal surface one centimeter per second when an oil film separates that surface one centimeter from a fixed like surface—a scientific measure of "drag". The unit of absolute viscosity is the *poise.* To find absolute viscosity requires laboratory technique, so for practical purposes viscosity is usually measured by observing the time in seconds required for 60 cc. of the oil to flow through a standardized orifice in a Saybolt Universal viscosimeter (there are also Redwood, Barbey and Engler units). It is customary to make the determination on oil at 100, 130, or 210 F. In specifying viscosity, give the temperature and the name of the viscosimeter used—for example, 400 sec. Saybolt Universal at 130 F. Saybolt viscosity seconds are not proportional to absolute viscosity poises except in the range above 200 sec. But the time of flow is proportional to absolute viscosity divided by oil density. This ratio is called *kinematic viscosity* and the unit is called a *stoke.*

Viscosity is important because it indicates heat produced, rate of oil flow and the resistance oil offers to a shaft turning in its bearing. The lower the viscosity, the lower the friction in the journal, but oil must always be viscous enough to maintain a film between bearing and shaft. Also, the thinner the oil, the quicker it will distribute over bearing surfaces and so decrease wear. Viscosity has been pretty well standardized for various services—See "How to Choose Oils", page 328, or your lubrication engineer or oil supplier.

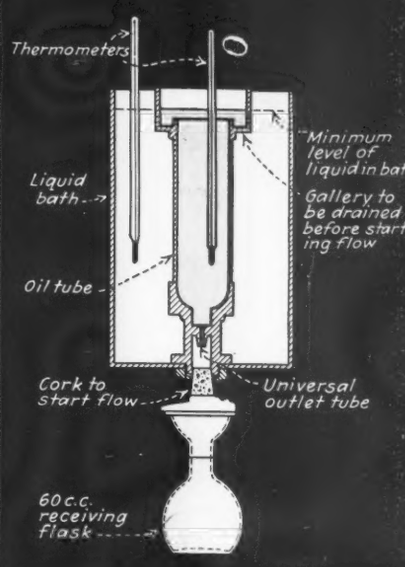
Viscosity Index, a comparatively recent term, is a measure of the relation between the viscosities of a given oil and an average Pennsylvania and an average Coastal oil at 100 F, all three having the same viscosity at 210 F. From tables, viscosity index may be calculated from tests of only the oil in question. A high-V.I. oil does not become excessively thin when heated nor thick when cooled. For most services, high V.I. is desirable. In internal-combustion engines, for example, high V.I. is particularly desirable.

Specific Gravity is simply the weight of oil compared to the weight of an equal volume of water, both at 60 F. But the commoner standard of measurement is A.P.I. gravity, measured by a hydrometer-like instrument with a different scale. The reading for pure water at 60 F is 10, for kerosene about 42, fuel oil about 30, and gasoline 58 to 70. Specific gravity equals 141.5 divided by 131.5 plus the A.P.I. scale reading.

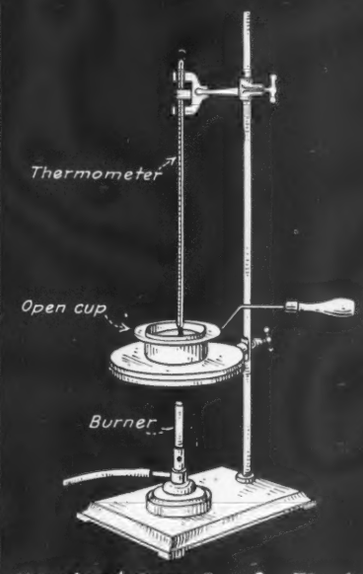
Gravity is of little value as an index to quality of a lubricant. As oil is frequently sold on the basis of volumes delivered corrected to 60 F, gravity must be known to make proper corrections. An experienced engineer can identify the crude from which an oil is made, by V.I. or gravity.

Flash Point—At a certain temperature, oil heated in a cup vaporizes so rapidly that it will ignite momentarily when a flame is brought close. When oil vaporizes fast enough to keep on burning, it has reached its *fire point.* But oil at temperatures above its flash point can still retain its lubricating properties. Flash point as a specification for lubricating oils is actually a makeshift to compensate for a large factor of ignorance. An oil with low flash point will generally evaporate more rapidly in service than one with high flash point. The tendency to evaporate may be important, as in internal-combustion engines.

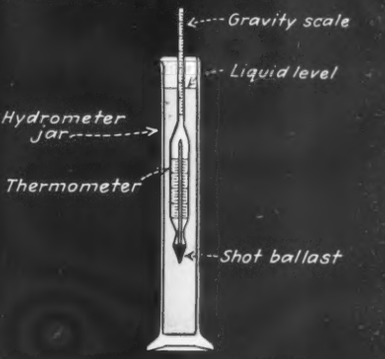
Pour Point—As an oil is cooled it resists pouring more and more, until finally it refuses to pour. In making tests for pour point, oil temperature is lowered progressively in steps of 5 F. At each 5-deg. interval, the test jar is removed from the cooling bath and tilted for 3 sec. As soon as the oil does not flow when tilted, the test jar is placed horizontal for 5 sec. If no movement takes place, pour point is 5 deg. above this non-flow point. Pour point is vitally important on lubricants for low temperatures, in refrigerating machines and equipment outside in cold weather. As some oils are cooled, separation of wax becomes visible before the pour point is reached. This is the *cloud*



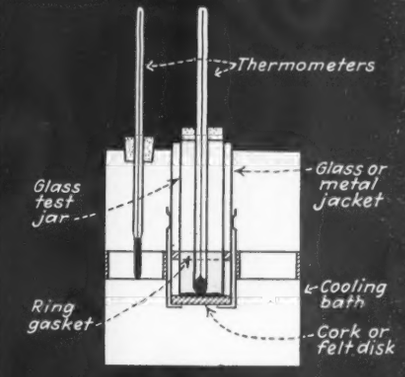
Saybolt Universal Viscosimeter



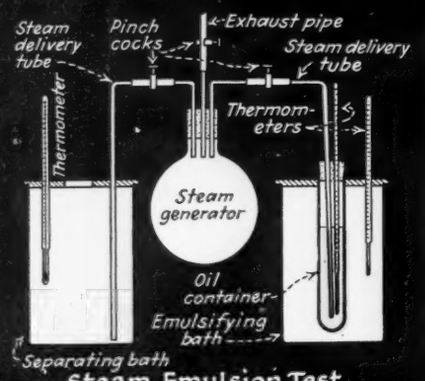
Cleveland Open Cup for Flash and Fire Tests



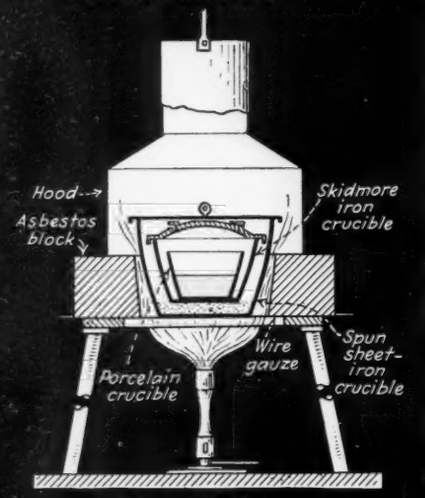
Hydrometer for Determining Gravity



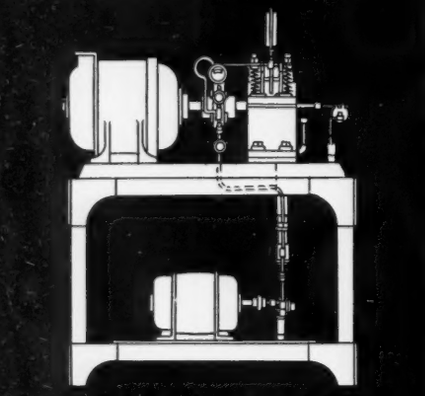
Cloud and Pour Test

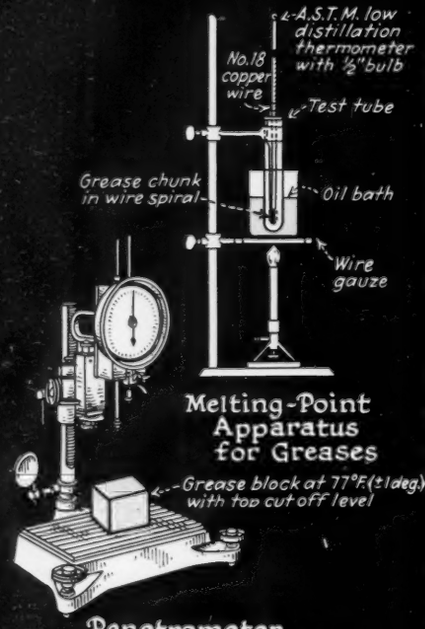


Steam Emulsion Test



Carbon Residue Test


Navy Oil-Endurance Tester


A.S.T.M. low distillation thermometer with ½" bulb
No. 18 copper wire
Test tube
Grease chunk in wire spiral
Oil bath
Wire gauze
Grease block at 77°F. (±1 deg.) with top cut off level
Melting-Point Apparatus for Greases

Penetrometer for Testing Greases

point and of value with wick feed. However, this test is misleading if water is in the oil. Oils that are not dewaxed normally have high pour points, as wax solidifies and interrupts flow.

Emulsification—Oil, thoroughly mixed with water, forms an emulsion which generally tends to separate on standing. Some oils contain sulphonates, certain acids, alcohols and finely divided earthy matter which retard separation. There are two methods of determining emulsification properties, one the steam emulsion test and the other a water test. The number of seconds required for an oil to completely separate from an emulsion when steam is passed through the oil in a standardized manner is the *steam emulsion number.* In the water method, an emulsion is formed by churning for 5 min. 27 cc of oil and 53 cc of distilled water at either 130 or 180 F. If complete separation is obtained in 1 min., an oil is said to have perfect demulsibility.

Oils for turbine lubrication must separate readily from water, hence emulsification tests for such oils are nearly as important as viscosity tests. For certain types of marine engines, the opposite is true. For oils for air compressors, internal-combustion engines, and machinery in general, emulsification tests are of little value.

Precipitation Number—An indication of the amount of asphalt or tar present, determined by diluting 10 cc of oil with 90 cc of special petroleum naphtha. Deposits are separated by centrifuging, and the volume of the separated layer in cubic centimeters is the precipitation number. In general, asphalts are undesirable, although black oils for lubricating open gears usually have high precipitation numbers. In tests to determine amount of sludging in used oils, precipitation number is significant.

Corrosion Test.—The Bureau of Mines places a clean strip of pure polished copper in a sample of oil held at 212 F. for 3 hr. The strip is then washed in sulphur-free acetone and compared with a fresh copper strip. Discoloration or pitting indicates corrosive constituents. Corrosion of bearing metal is often due to moisture in the oil, so it is highly important to eliminate sources from which oil may collect moisture.

Water Test—Water gives all but the darkest oils a cloudy appearance, and its presence can be detected by heating a sample of oil to a few degrees above 212 F. If cloudiness is due to water, the oil will become transparent. Water retards the capillary action of wick feeds because it wets the wick.

Wick-feed Test—This test requires 14 days and involves measuring the quantity of oil lifted by capillary action through a wool wick. It is intended to simulate service conditions, and results are interpreted by comparison with those on known oils.

Specific Heat.—A pound of oil will absorb about 0.47 B.t.u. per deg. of temperature rise—of importance when oil is used to cool a bearing or piston. If the amount of heat to be removed per min. is divided by the specific heat (0.47), the answer is the number of pounds of oil which must be circulated per min. if the oil is to rise only 1 deg.

These are all physical tests, most of them useful in determining the suitability of an oil for a given service. There are also a number of chemical tests of real importance:

Sulphur Test—Total sulphur content is tested in a bomb and should be undertaken only by an experienced chemist; furthermore, total sulphur content has no known significance. The presence of sulphonates indicates overtreatment with sulphuric acid or inadequate washing. As sulphonates are strong emulsifying agents and tend to promote sludge, they should not be present. The Engineering Experiment Station at Annapolis has developed a test in which 60 cc of HCl and 50 cc of ethyl ether are added to 150 grams of oil, and the mixture boiled for 1½ hr. The acid is then separated out in a separatory funnel. After evaporation to a few cc and dilution with distilled water, a drop of 10% barium-chloride solution is added. Presence of sulphonates is indicated by precipitation of barium sulphate.

Carbon Residue—This test involves destructive distillation in apparatus designed to exclude air, to permit control of heating rate and to eliminate condensation of distillates. The non-volatile residue is termed *carbon residue.* Many bearings, such as in internal-combustion engines, operate at high enough temperature to cause chemical changes in the lubricant and so produce deposits that clog oil passages and cause wear. It has been said that carbon deposits in an engine are proportional to the carbon residue of the lubricating oil. Other authorities, however, claim other factors may dominate.

Neutralization Number—Acidity of an oil is indicated by its neutralization number, which is the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. It expresses the total amount of mineral and organic acids. The test is made by dissolving the acids in alcohol, then measuring the potassium hydroxide necessary to neutralize them, using phenolpthalein as an indicator.

While acids are not harmful under all conditions, nevertheless their presence may lead to corrosion and formation of sludges, emulsions and deposits. Generally speaking, neutralization number shows the degree of refinement of a new

oil and the amount of deterioration in a used oil.

Saponification Number—This test is applied only to a compounded oil or to a suspected mineral oil to find out whether it has been compounded with an animal or vegetable fatty material. The number of milligrams of potassium hydroxide required to saponify one gram of oil is the saponification number. As standardized, this test requires laboratory technique.

Accelerated Service Tests.—There are a number of lubrication-testing machines designed to compare service characteristics—usually a motor-driven journal, a plain bearing arranged so that a specified load can be applied, and a lubrication system. One machine is loaded until seizure occurs, others operate at constant load, and the quality of the lubricant is determined either by testing the oil to determine changes in viscosity, neutralization number and carbon residue, or by visual examination of bearing condition.

Grease—Tests to determine the quality and nature of a grease have not been standardized as have tests on oil. A few, such as flash point and corrosion, are similar. Several different tests have been developed for such physical characteristics as melting and dropping points and consistency. There are no tests, however, for color, odor, texture, elasticity, or stability in storage other than general experience and observation.

Melting and Dropping Points—These terms are often used synonymously, although melting point is usually a few degrees under dropping point. At operating temperatures over 100 F, dropping or melting point becomes important. One method of determining the drop point is to place a drop of grease on the bulb of a thermometer inside a 1x6-in. test tube. Place the tube in an oil bath and raise the temperature 1 to 3 deg. per min. until a globule of grease drops from the end of the thermometer. The average of five determinations is the drop point.

Consistency—No standard unit has been adopted for expressing consistency of grease, generally understood to refer to flow-pressure characteristics. Methods and apparatus have been developed for determining these characteristics and give the best measure of consistency, but they take too long for general commercial use. Penetration tests use a cone of standardized weight and shape dropped from a specified height into the grease within 1 deg. of 77 F. Depth of penetration in hundredths of a centimeter is observed.

Consistency changes after a grease has been worked, also varies with temperature. In greases of the same type, consistency may be considered to be a measure of soap content, an important property. To a great extent it determines bearing friction and rate of flow through a bearing or in a centralized system.

Odor—Most fats have objectionable odors that may be detected in the grease. Special-purpose greases are sometimes scented to mask these odors, but scenting in a general-purpose grease may have been done to mask a rancid, unstable fat.

Texture refers to grease structure and is described by terms such as smooth, fibrous, spongy, etc. *Elasticity* is the ability of a grease to return energy it has absorbed and is referred to as rubbery, stringy, short, cheesy.

A complete method of chemical analysis has been laid out, but is too complex and lengthy for any but a chemist. From it may be determined ash content, fillers, soap, fat, petroleum, free alkali, free acids and water content. However, two greases showing almost identical analyses may show marked variations in lubricating performance. Hence, from a practical standpoint, physical properties are more important.

Specifications—Most large users have developed their own specifications for lubricating oil, which have resulted in the purchase of lubricants that give satisfactory service for their particular conditions. As small users may not have specifications, detail requirements of the U.S. Navy are given in the table for some lubricants that *Power* readers may be called upon to use. Symbols at the top of the table are used by the Navy. The first digit refers to the class of oil, i.e. (1) aviation oil, (2) forced-feed oil, (3) forced-feed oils (V.I.75 min.), (5) mineral-marine engine and cylinder oils, and (6) compound steam-cylinder oils (tallow). The last three digits refer to Saybolt universal viscosity seconds. Oils specified by the Navy for different uses are given below by symbols used in the specification table.

SERVICES AND NAVY SYMBOLS

AIR COMPRESSORS (Horizontal, Multi-Stage)
- Air cylinder—2190 or 3050
- External lubrication, sight-feed and wick-Oil cups, or hand oiling—2135, 2190 or 3050
- External lubrication, circulation systems, or splash-type crankcases—2110, 2135 or 3050

DIESEL ENGINES
- Cross-head type, vertical, power cylinder using forced feed—3100, 3120 or 1150
- Bearings using circulating or pressure system—2190, 2250, 3050 or 3065
- Trunk-piston type using same oil for bearings and cylinder—2190, 2250, 3050 or 3080

GENERATOR
- Turbo—100 kw. and smaller—2110 or 3050
- Turbo—100 kw. and larger—2135 or 3050
- Turbo—without circulating system or water-cooled bearings—3100 or 3120

MOTOR (Electric)
- Sleeve or ring bearings—2190 or 2250
- Ball or roller bearings—1150

STEAM ENGINES
- External lubrication, sight-feed and wick-feed oil cups—2135 or 2250
- External lubrication, circulating systems, or splash-type crankcase—2110 or 2135
- Cylinder lubrication, superheated steam up to 300 lb. where condensate is used for boiler feed—5190
- Cylinder lubrication using wet steam about 100-lb. pressure, load less than 75%—6135
- Cylinders of non-condensing engines and pumps—6135
- Cylinder lubrication, condensing engines, condensate not used—6135

STEAM TURBINES
- Bearing using circulating system
  - Temperature not over 140 F.—2110 or 2135
  - Temperature over 140 F.—2135 or 2190
- Reduction gears—2190 or 2250
- Speed reducers—2250, 3065 or 1150

TABLE I—U. S. NAVY OIL REQUIREMENTS

SYMBOL	1150	2110	2135	2190	2250	3050	3065	3080	3100	3120	5190	6135
Color	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Reaction	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Neutralization number, maximum	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	1.00
Fixed or fatty oils, percent	None	None	None	None	None	None	None	None	None	None	None	5–7
Nature of fixed or fatty oils												(3)
Precipitation number, maximum	None	None	None	None	None	None	None	None	None	None	0.05	0.05
Free sulphur or corrosive compounds	None	None	None	None	None	None	None	None	None	None	None	None
SO_3 as sulphonates	None	None	None	None	None	None	None	None	None	None	None	None
Water	None	None	None	None	None	None	None	None	None	None	None	None
Carbon residue (%), max.	1.50	0.20	0.30	0.40	0.50	0.30	0.50	0.80	1.00	1.25	4.00	2.50
Nature of carbon residue	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Ash (percent), maximum	None	None	None	None	None	None	None	None	None	None	0.05	0.05
Total sulphur (percent), max.	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.75	0.75	0.75	0.50	0.50
Nature of oil	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)
Flash point (deg. F), min.	510	325	340	350	370	390	410	440	460	480	525	475
Pour point (deg. F), max.	30	0	0	35	35	0	5	15	25	30	60	60
Viscosity, Saybolt Universal:												
At 130 F. (seconds)		90–120	120–145	185–205	245–280							
At 210 F. (seconds)	140–160					45–55	60–70	75–90	90–105	115–125	180–220	120–150
Viscosity — Index (Dean and Davis), minimum	95					75	75	75	75	75		
Emulsion test (time to settle out (minutes), maximum):												
Distilled water at 130 F.		30	30	30		30						
1 percent salt solution at 130 F		30	30	30		30						
Normal NaOH at 130 F		30	30	30		30						
Boiling water at 130 F		30	30	30		30						
Distilled water at 180 F.	60				60		60	60	60	60		
1 per cent salt solution at 180 F	60				60		60	60	60	60		
Emulsifying constituents with steam		None	None	None	None							
Wick feed Test												

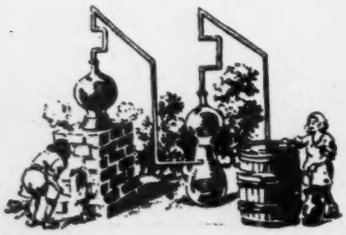
No minimum requirement. In each case determination is made as a matter of record.
[2] Reaction to be neutral in all cases.
[3] Tallow oil.
[4] Loose and flaky in all cases.
[5] Mineral.
[6] Compounded.

SOURCES OF MINERAL OILS

REFINEMENTS IN REFINING

5,000 B.C.-Bitumen Used by Egyptians for Embalming

484-424 B.C.-Processing Oil from Water by Settling



1,552 A.D.-Distilling Crude Oil

What's in a Lubricant?

• There are three types of oils: animal, vegetable and mineral.

ANIMAL—Animal oils, "compounded" in steam-cylinder lubricants with mineral oil, include tallow and lard oils and degras. Tallow oil is obtained by pressing beef or mutton tallow, lard oil by pressing pig fat. Degras is prepared from the grease in sheep's wool. All contain fatty acids and much oxygen in addition to the fundamental hydrogen and carbon. All absorb more oxygen to dry out, and eventually turn rancid to form acids which attack metals. Tallow is used in white greases and as a saponified base to "hold" lubricating oil in a grease. Unrendered tallow—the familiar suet—will sometimes lubricate badly worn open bearings. Lard oil is used in cutting oils, in some engine lubricants (to 10%) and in stainless oils.

Other animal oils include neatsfoot, sperm, whale, porpoise jaw, dolphin jaw, melon, menhaden, cod, and other fish oils. Neatsfoot, from boiling cattle hooves and bones, is a special-purpose, non-drying oil for lubricating fine instruments and treating leather. Sperm and whale oils come from whale blubber, sperm having the lowest viscosity and specific gravity of any *fixed* (decomposes if distilled) oil. Sperm oil and pale whale oil are used in textile lubricants, for cutting oils, etc. Dark whale oil is useful only for quenching. Seal oil, from seal blubber, is similar to whale oil.

Soft fat in the head and jaw of the porpoise and dolphin produce oil; melon oil comes from a melon-shaped lump of fat in the dolphin's head. These are expensive and used principally for lubricating watches and other fine mechanisms. Other fish oils are used for leather treating, quenching and tempering; some marine lubricants contain cod oil. Wool grease, called "Yorkshire grease," makes rolling-mill and colliery greases.

VEGETABLE—Vegetable oils are similar chemically to animal oils, although they usually dry more readily. Castor oil, best lubricant among them, comes from the seeds of the castor shrub, and has the highest specific gravity and viscosity of any fixed oil. By tradition, it lubricates heavy marine, airplane (particularly rotary) and racing-automobile engines with extremely high bearing pressures. Castor does not mix well with mineral oils, unless another fixed oil (such as lard or rape) is present, but all other fixed oils do, and have been so used.

Rape oil, used in railway and marine engines, soluble and quenching oils, is extracted from Indian and Russian rape seeds. Cottonseed oil dries too readily to make a good lubricant, but is sometimes an adulterant in other oils, principally for marine engines. It gives good "finish" as a cutting oil. Linseed oil, pressed from flax seed, a drying oil, is useless as a lubricant. Olive oil, formerly a non-staining lubricant in wool processing, has now been mostly replaced by mineral oils. Cocoanut oil, from cocoanut meats, may be used in internal-combustion engine oils (3 to 10%). Palm oil and palm-kernel oil, from the African oil palm, closely resemble cocoanut oil. Peanut oil is similar to cocoanut. Mustard-seed oil is said to be like castor oil. Rosin oil is used in low-quality greases, soluble oils and belt dressings.

MINERAL—Petroleum, or crude mineral oil, is found in almost every country, although chief fields are in the United States, Venezuela, Colombia, Russia, Mesopotamia and Borneo. Most geologists claim it originated from decomposition under pressure of vast quantities of minute sea animals. Crude is a complex combination of hydrogen and carbon, varying with the field from which it comes in percentages of napthenes, paraffins and aromatics (the three principal types of carbon-hydrogen combinations. By careful refining, manufacturers remove asphaltines, wax, free carbon, and other undesirable constituents.

There are four large oil-producing regions in the United States. So-called "paraffin-base" crudes come from the Pennsylvania field; "mixed-base" crudes from the Mid-Continent field; western and most foreign fields produce "asphalt-base" crudes. Most lubricating oils are now "blended" of various crude stocks to gain a preferred group of properties.

SOLIDS—Graphite, talc, soapstone, mica, flowers of sulphur, white lead and similar materials are also used as lubricants; graphite resists pressure without breaking down, while amorphous graphite and flowers of sulphur break up.

Graphite, not attacked by acids, alkalis, or high or low temperatures, is a mineral and most important of all the solid lubricants. It is used extensively for lubricating locks, etc., where a liquid lubricant might cause small parts to stick. It is also mixed with semi-solid lubricants. There are also water and oil mixtures with an artificial amorphous graphite produced in the electric furnace.

Talc and soapstone are occasionally found in finely powdered form in greases and thickened oils. Mica, a general term for several kinds of minerals alike in the facility with which they split into thin flexible layers, is powdered for thickening oils and greases.

OTHERS—Two other very common but unrecognized lubricants are water and air. Water lubricates steel shafts in wood or rubber bearings under water, as on hydro turbines. Moisture in vertical steam cylinders does some lubricating there. Air (under pressure) is the lubricant in some new high-speed centrifuges, and was applied by Kingsbury in a small wedge-block thrust bearing.

LUBRICATING OILS—Dark cylinder oils, chiefly for lubricating steam-engine valves and cylinders, are mineral-oil residues freed from solid impurities, and may be mixed with 3 to 10% acidless tallow oil or degras. Filtered cylinder oils, filtered from the dark oils, give high quality steam-cylinder lubricants. They may be mixed with 3 to 12% acidless tallow oil or lard oil. Mixed with lower-viscosity oils, they produce internal-combustion, air-compressor, and engine oils.

Red oils are fire-distilled, acid-treated oils, the base for medium- and heavy-viscosity oils for general lubrication. Mixed with filtered cylinder oil, they produce very heavy-viscosity engine and machinery oils. If from paraffin-base crude, they produce a good deal of hard and brittle carbon, making them unsatisfactory for internal-combustion engines (asphalt-base crudes produce a softer, more crumbly carbon deposit). Heavy red oils mixed with a 5 to 20% fixed oil (animal or vegetable) produce some lighter-vicosity marine and engine oils.

Pale oils are fire-distilled and heavily acid-treated or filtered. With light-to-medium viscosity, they lubricate quick-running machinery and form a base for yellow greases. Alone, or mixed with 3 to 10% fixed or filtered cylinder oil (for heavy-viscosity oils), they are lubricants for small internal-combustion engines.

Natural oils are distilled, bleached and filtered, and form the base for most kinds of circulated oils, such as in self-oiling bearings, steam turbines, etc. They separate well from water, and may be mixed with filtered cylinder oil. By redistillation, they may be separated into viscous and non-viscous oils.

Dark lubricating oils are undistilled residues with low viscosities, used alone or mixed with low-viscosity lubricating oils in cheap lubricants and black greases.

Viscous low-setting-point oils are fire-distilled from non-paraffinic base crude, acid-treated and filtered. Compounded with 10 to 25% fixed oil, they form heavy-viscosity railway and marine-engine oils, also heavy-viscosity internal-combustion-engine oils because they produce only a little soft carbon.

Non-viscous, low-setting-point oils are distilled, acid-treated and possibly filtered. Non-paraffinic base crudes give low setting points, may be cold-pressed to reduce wax and thus lower setting point for refrigerating-compressor oils.

Bloomless oils are neutral, highly filtered and possibly bleached, having light viscosity. They are in "stainless" oils and for adulterating edible oils.

White oils are acid-treated or filtered to remove color and used for transformer oils. It is hard to decolor paraffin-base crudes. Medicinal white oils are similar, but treated to remove taste and odor.

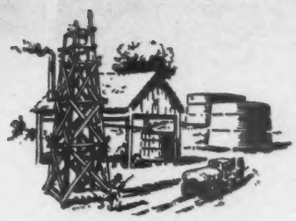
GREASES—Greases consist of a soap base and a mineral oil primarily, although this term also covers mineral oil thickened with solids and various compounded or blended heavy oils. Animal or vegetable oils, called fats, are saponified with alkali, then mineral oil is added. Depending upon the alkali, they are classified as lime-base (general-purpose, slow-speed, up to 175 F, made with slacked lime), sodium-base (high-temperatures and speeds, emulsify, for bearings and centralized lubrication; made with caustic soda), mixed-base (combines characteristics of above, as in high-speed bearings in water; made with calcium hydroxide) and aluminum-base (high speeds and temperatures; made with aluminum hydroxide).

Cup grease is a lime-base with 10 to 20% fat, preferably beef tallow. A little emulsified water gives proper consistency, and melting point is 120 to 200 F, depending on soap content. White cup grease, higher priced, is usually made with mutton tallow and very little mineral oil. Melting point is low, and it may include mica (then called mica grease).

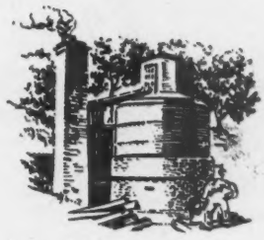
Fiber and sponge greases have high melting point and peculiar fibrous structure, and although they emulsify readily, are good for bearings. Ball- and roller-bearing greases are soft and of higher quality. Petroleum greases are made cold by dissolving soaps in mineral oil.

Graphite grease is usually cup grease with 5 to 20% flake graphite. Gear greases are made with the heavier lubricating oils, hence have high melting point, adhesiveness and absorb shock loads. Axle greases are similar, but include rosin oil and often talc, mica, etc., for filler. Wool and yarn greases are really cup greases containing short lengths of woolen or cotton yarn; for heavy-duty, slow-speed bearings. Mine-car greases are cheaply made from rosin and heavy lubricating oils, with much water and filler. Wire-rope greases are similar, plus possibly wool or stearing pitch.

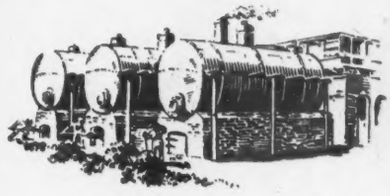
Launching greases, unsuitable for bearings, are mixtures of dark lubricating oils and tallow substitutes. Hydraulic greases are often mixed with rosin, tar or other fixed oils. Heavier rolling-mill greases are mixtures of dark and heavy lubricating oil stock and rosin or pitches, plus solid lubricants for filler. Anti-rust grease is usually mixed neutral petroleum jelly and heavy mineral oil.



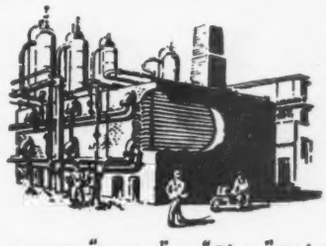
1860-Early Refinery



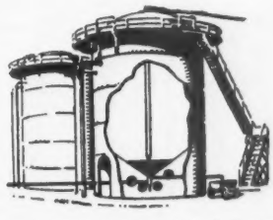
1865-"Cheese-Box" Still



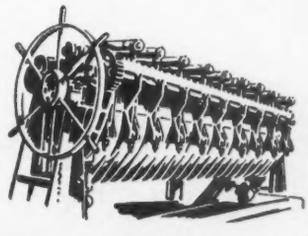
1890-"Shell"-Type Stills



1900-"Tube" or "Pipe" Still



1905-Batch-Type Acid Agitator



1910-Sweetland Pressure Filter

1932-Modern Solvent Extraction Plant

How to Lubricate

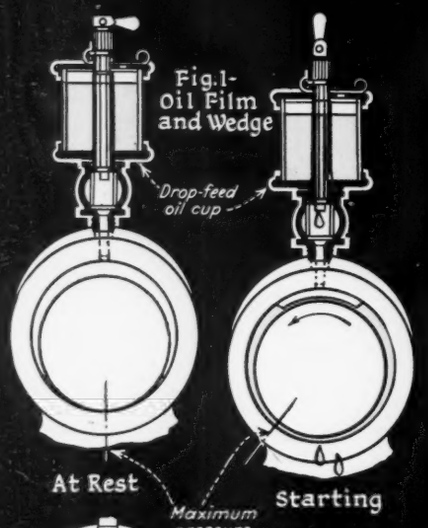


Fig.2-Kingsbury Thrust Bearing Slipper

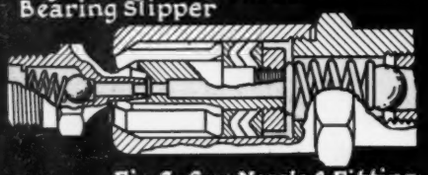


Fig.3-Gun Nozzle & Fitting

Fig.4-Temperature-Regulated Oil Cup

Fig.5 Bottle Oiler

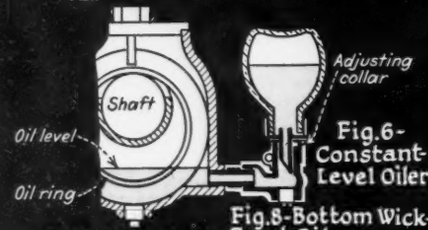
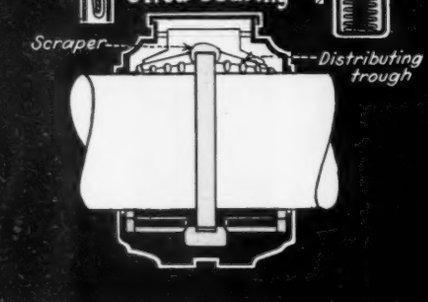


Fig.6-Constant-Level Oiler

Fig.7-Wick-Feed Oil Cup

Fig.8-Bottom Wick-Feed Oiler

Fig.9-Collar-Oiled Bearing



• Any transportation system must have terminals to handle passengers. In lubrication, the starting point is the oiling or greasing device, the terminus is the lubricated surface, and the passengers are the proper lubricants.

A journal at rest lies at the bottom of its bearing, Fig. 1a, probably having squeezed out the oil and thus being in contact with the bearing metal. The operator, in starting, opens the feed and oil begins to fill the clearance, its spreading made easy by the absorbed oil film still on the surface. The journal begins to rotate, and its metal-to-metal contact causes it to climb the side of the bearing, Fig. 1b. Oil level rises until oil flowing in equals that flowing out; there is high friction and starting effort.

The journal moves faster, and the oil wedge just above the point of contact is forced into an ever-narrowing clearance space, creating hydraulic pressure highest at the very tip of the wedge. Suddenly pressure becomes so great that the wedge slips under the journal, and the sudden drop in friction and turning effort allows the journal to drop to the bottom of the bearing again, Fig. 1c. Riding on an oil film, the journal turns faster and faster, increasing the hydraulic pressure at the tip of the oil wedge until it forces the journal over toward the opposite side, Fig. 1d, the normal running position.

In drop-feed oiling, limited oil supply limits the crowding action, but the flood circulation created by pressure oiling makes it very pronounced. In the maximum-pressure area, the oil film is only a few ten-thousandths to a thousandth or so thick, but it is laminated—a layer of adsorbed oil clinging to each surface and layers moving between.

This wedge principle has its uses in all oiling—for example, the slipper pad on an engine crosshead has a chamfered end to set up the same action and force the oil under it. Kingsbury used the idea in his thrust bearing; Fig. 2, pad 2 rocking over support 3 and thus allowing the wedge-shaped perfect oil film to form between the pad and collar 1.

So to oiling devices. The simplest is the hand squirt can, either a push-bottom or pushbutton type, delivering oil to drilled holes (which should be covered with caps or buttons) or felt-lined troughs. Cheap and convenient, it is wasteful of oil, undependable, and prone to dirt and under-lubrication (or over-lubrication, just as bad in anti-friction bearings). The push-bottom type allows no control of the "squirt," the pushbutton (or pump) type delivers oil only as long as the button is pushed. Low-speed bearings, open gears, chains, wire rope, etc., on rough or cheap machines are thus lubricated. An improvement is the pressure-gun arrangement, Fig. 3, with check-valve fittings of many types serviced by plunger guns, also with check valves, so pressures up to 10,000 lb. per sq. in. can be built up.

Single- or multiple drop-feed cups are undependable and wasteful, but can handle unimportant plain and anti-friction bearings, chains, gears, etc. They must be started and stopped by hand, Fig. 1a and b, are inefficient and irregular, but cheap and adjustable to some extent. They may vary 700% in feed with a 50-deg. temperature variation, and 150% from full to empty—if flow is adjusted properly to minimum temperature and head, they overfeed most of the time. Needles become clogged and dirty too. There is the temperature-regulated type, Fig. 4, in which bearing-temperature variations are transmitted to air in the cup, forcing more or less oil down as required. There is also the constant-level type, Fig. 6, used on ring-oiled or anti-friction bearings.

Wick-feed cups and boxes, Fig. 7, on small motors and simple bearings, incorporate a wick, several wicks, or a long pad. The pad may be pushed up by springs or rest on the journal, which pulls off some soaked-up oil. Wick types combine capillary and siphon action. They are cheap, moderately efficient, adjustable (through adding or taking off wicks and by adjusting wick length), reliable, but must be cared for by hand and are irregular. Feed varies widely with oil level. The lower end of the wick is on a wire holder withdrawn to stop oil flow. The outer end of the wick will show no flow if hanging less than $\frac{1}{4}$ in. lower than the inner, but beyond that increase to 1 drop every 4 sec. with a 4-in. difference in length. Because of the siphoning action, the higher the wick lifts oil, the less the flow, $\frac{1}{8}$-in. lift giving a drop every 10 sec., and 2-in. lift giving a drop every 65 sec. in one test. This means that oil level should be held as near constant as possible. Bottom-feed wick oilers have a reservoir below, the wick being held by spring against the journal and feeding only when the journal turns. Oil level in these stays fairly constant.

Bottle-oilers, for plain horizontal bearings on conveyors, etc., are simply oil bottles inverted over the oil hole, a feed wire extending through the bottle cap down to the journal. Heat generated by the journal is conveyed up the wire to the air space over the oil, creating pressure which, combined with up-

and-down movement of the wire, feeds oil down to the bearing when the journal is operating, Fig. 5.

So-called "oil-less" bearings actually depend on a lubricant of some sort. Some types are pressed, powdered metal, with about 20% of the initial volume oil filling intergranular spaces. Other types are lignum vitae, maple or pine impregnated with oil or graphite or both. Most of these are fed new oil through a wick or other arrangement.

For efficiency and economy, it is sensible to use oil over and over again. Simplest of such arrangements for horizontal bearings are the ring, chain and collar oilers which appear on small turbines, fans, motors, blowers, centrifugal pumps, steam engines and lineshafts. They are automatic, reliable, efficient, regular, clean, and need but little attention. All incorporate an oil reservoir, filled to about half a diameter away from the journal for ring and chain arrangements, and closer for the collar type, Fig. 9. Collars, for very low speeds, simply run in the oil bath, carrying clinging oil to the top where a scraper redirects it to perforated troughs at each side. Used oil drops back to the reservoir. Chains handle higher speeds, but at high speeds begin to churn. Rings, for high speeds, are of various shapes, usually twice journal diameter and 1-piece. They may feed poorly at first, so some are notched inside for faster starting. One ring, Fig. 22, will handle a journal up to 8 in. long, with 1 additional ring for each added 8 in. of journal.

Ring or chain types, and other high-speed arrangements, require oil seals or oil throwers. Two throwers are shown in Figs. 8 and 10. They are simply collars designed to catch oil working out along the shaft, forcing it back into the reservoir. Oil seals are packing or baffles.

Vertical shafts, enclosed gears, chains, wire cables, thrust bearings, plain and anti-friction bearings that can be put in oil-tight housings usually run in oil baths, Fig. 10. First cost is high, but the system is automatic, efficient, reliable, regular and requires minimum attention. Somewhat similar is splash oiling, which also requires an oil-tight housing, but must keep oil at the proper level—otherwise it fails entirely. Reciprocating or rotating elements splash oil over other parts, as on enclosed gears, crosshead pins and guides on steam engines, internal-combustion engines, compressors, etc. If a catch trough or boat be put in the proper position, Fig. 13, the system can be made circulating. Again, there is the manually operated non-circulating system, Fig. 19.

Circulation oiling for high-speed heavily loaded bearings, high-grade gearing, steam turbines, fans, blowers, etc.—has high first cost, but feed is adjustable, automatic, reliable, positive, regular and efficient. Oil is carried from a supply point through drilled passages or tubes to oiled surfaces, from which it drains to a sump. The gravity type incorporates a small pump which lifts oil from the sump to a supply tank above the highest bearing to be lubricated, from which oil flows by gravity. The pressure type has a rotary, gear or centrifugal pump pumping direct.

Force-feed lubricators are all similar in principle, incorporating one or more plungers similar in action to a simple tire pump, energized by a camshaft which may be lever, belt or gear driven, Fig. 14. The lubricator is its own reservoir, and from this the plungers draw in turn a metered quantity of oil, which is forced to the desired point or group of points. This system on diesel engines permits a "shot" of oil to be forced against the piston when it is at bottom dead center. Usually, several openings are provided around the piston, and oil is "shot" between the first and second rings, the rings being distributors.

Hydrostatic lubricators have been used for years in steam-engine lubrication. They operate by using a head created by condensate from the line. The steam line is tapped 18 in. or more above the lubricator, Fig. 15. Steam enters condenser 2 through pipe 1, then is allowed to flow (as water) through valve 3 and pipe 4 to the bottom of oil reservoir 5, incoming water displaces the oil, forcing it down through pipe 6 and feed-regulating valve 7. Then oil rises through the water in sight-feed glass 8 and enters steam pipe 10 through delivery pipe 9. Of course, such a device must be started and stopped with the engine, and some oil is wasted each time it is refilled. Parts are likely to get dirty and clogged, and feed will vary with engine-room temperature and oil temperature.

Mechanical lubricators are now superseding the hydrostatic type. Operated from some moving part of the engine, they start feeding when it starts, and stop when it stops, varying feed with speed. Oil pipes leading to distribution points usually carry spring-loaded check valves so they are always full and yet do not waste oil into the steam line when the engine is not operating. Ratchet, rotary and clutch drives are applied.

When hydrostatic and mechanical types feed into steam lines, they require some form of atomizer. Simplest and best forms are simply pipes extending into the line, as in Fig. 16, cut at an angle facing steam flow and slotted beneath, or drilled on both sides so steam can get in and spray oil out.

A variation of the hydrostatic type used on air compressors is shown in Fig. 11. Oil container **a** is drained through feed-regulating valve **b**, main shut-off valve **d** and check valve **c**.

Fig.10-Oil Bath on a Vertical Shaft

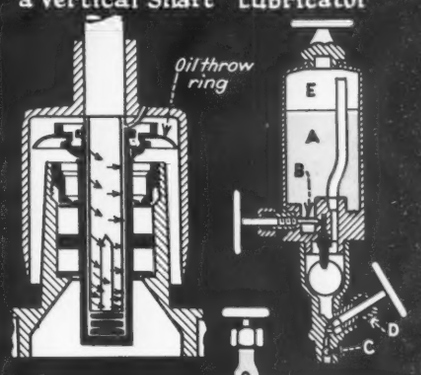


Fig.11-Sight-Feed Lubricator

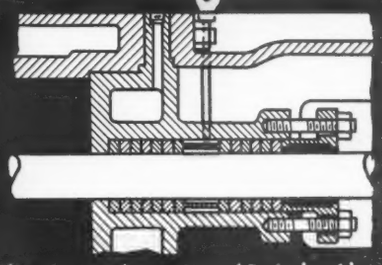


Fig.12-Lantern Gland Lubrication

Fig.13-Splash Circulating System

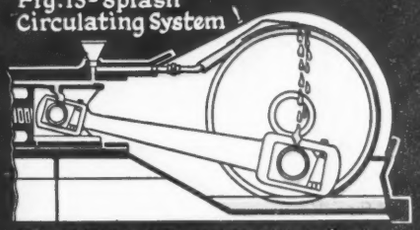


Fig.14(Below)-Forced-Feed Lubricator

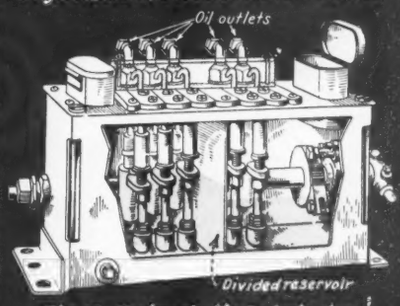


Fig.15-Hydrostatic Lubricator

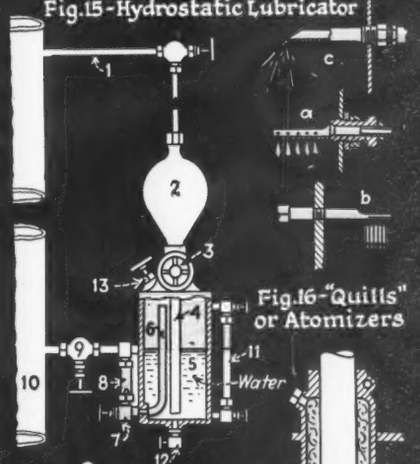


Fig.16-"Quills" or Atomizers

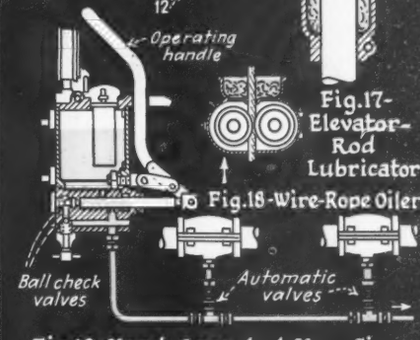


Fig.17-Elevator-Rod Lubricator

Fig.18-Wire-Rope Oiler

Fig.19-Hand-Operated, Non-Circulating System

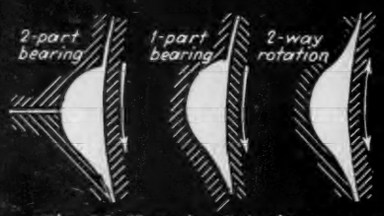


Fig. 20-How to Cut Oil Grooves

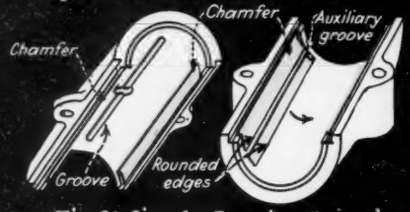


Fig. 21-Simple-Bearing Grooving

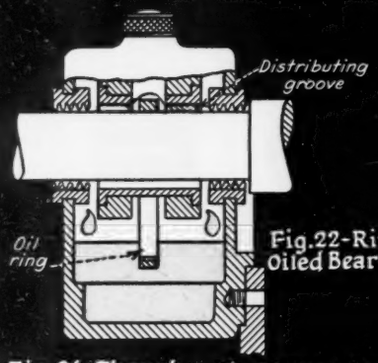


Fig. 22-Ring-Oiled Bearing

Fig. 24-Thrust-Bearing Oiling

Fig. 23-Grooving for Heavy Duty and Low Speed

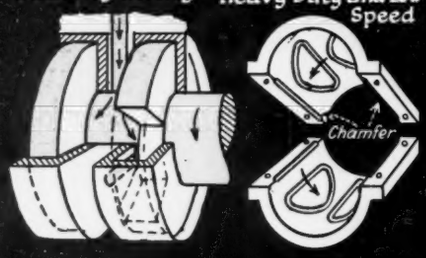


Fig. 25-Lubrication from Below (Belt Pulls Upward)

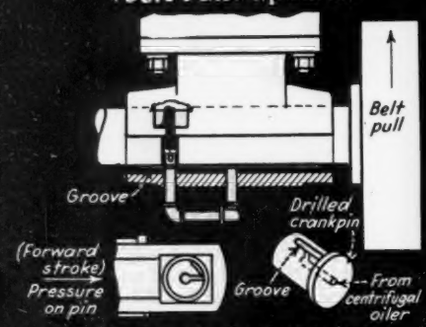


Fig. 26-Crankpin Grooving

Fig. 27-Bottom Crosshead-Guide Shoe

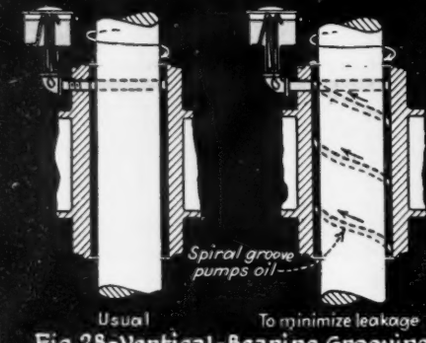


Fig. 28-Vertical-Bearing Grooving

Pipe e admits air over the oil, allowing the latter to run out by gravity.

Several specialized lubricating devices are shown in Figs. 12, 17 and 18. Fig. 17 is a hydraulic-elevator-rod lubricator. Fig. 18 shows a wire-rope oiler of similar type. Fig. 12 illustrates lantern-gland lubrication of a reciprocating plunger at higher speeds.

Grooving—Assuming that the correct amount of proper oil is being supplied to a bearing at the right place, the next job is to distribute it uniformly and quickly so that sufficient hydraulic pressure will be developed and maintained in the pressure area to float the journal. In high-speed, light-load bearings, wedging action of the shaft itself will aid in oil distribution and help the journal to float. But in the low-speed, heavily loaded bearing, there is constantly a tendency to squeeze the lubricant out of the pressure area, particularly if the journal stops, as well as to carry the lubricant downward in a narrow band into the pressure area, without giving it a chance to spread evenly. To counteract this, former practice was to cut criss-crossing or "figure 8" oil grooves. But these harmed instead of helped, because they connected high-pressure and low-pressure areas of the bearing and helped the oil to squeeze out. Also grooves were deep and narrow, unchamfered, and extended too close to bearing edges—all tending to destroy the thin oil film.

Grooves should be wide and shallow, Fig. 20, instead of narrow and deep, but not over-wide because that removes useful bearing area. Sharp sides scrape oil off the journal, so a groove must have its edge chamfered in the direction of rotation. V-shaped grooves have small capacity and may act as crack-starters. Even a simple oil hole should be chamfered on the side toward which the journal rotates, and a groove feeding a shaft rotating forward and backward must be chamfered on both sides. This little change helps the oil's wedging action. Sharp-edged bearing linings or protruding shims at joints of part bearings also act as scrapers, unless chamfered. But don't chamfer all the way to the end—for that simply provides a short and easy way out for oil.

Now, regarding location: Place grooves outside the high-pressure area and parallel with the axis of the shaft. A single longitudinal groove extending to within ½ in. of the bearing ends will aid distribution, Fig. 21a, even in many high-speed bearings. In 1-piece shells, this groove is placed diametrically opposite the pressure area (in other words, at the top), in 2-part bearings it is replaced by chamfering the edges of the cap and base, cutting back shims or liners to correspond. Normal wedging action draws oil downward and outward. This groove on the entering side spreads the oil and on the leaving side tends to collect any excess and feed it back toward the middle. In 90% of the cases, this grooving is enough. Four-part bearings are similarly chamfered.

If bearings are unusually long, the normal bearing clearance of 0.001 in. per inch of shaft diameter may not be enough to allow the oil to spread the width of the journal, so the edge chamfers in a part bearing may have to be supplemented by an oil-distributing groove where the oil is introduced. If bearing length is over 8 in., use more than one point of distribution and connect them with a distributing groove.

Ring- or chain-oiled bearings, Fig. 22, likewise should have the longitudinal groove for distribution, but in this case it is cut through to the ends, because oil that goes on out simply falls back into the well and is not wasted. Collar oiled bearings should have an oil scraper at the top to spread oil to the trough.

Heavily loaded bearings running at less than 50 r.p.m. may require one or a series of triangular grooves, with bases parallel to the axis and in advance of the point, Fig. 23. It serves to trap oil and force it back toward the center of the bearing. Another arrangement is a supplementary trough or groove just ahead of the pressure area which assures adequate supply at this vital point, Fig. 21b. If the shaft rotates in both directions, one groove should be cut at each side of the pressure area, about 30 to 45 deg. before the point of maximum pressure. Some special half-bearings lubricated with force-feed systems have these grooves cut inside the pressure area but away from the maximum-pressure area, and oil is delivered directly to them. This is the best method where bearings are subjected to upward pressure, although under low load, a longitudinal groove can be cut in the bottom and oil introduced there, Fig. 25.

Vertical bearings are usually just guide bearings carrying but little journal pressure. Lubricating film is lost only through bottom leakage. In some cases, no grooving is required, and in most cases, an annular groove at the top to assist in oil distribution will do the trick, Fig. 28a. If leakage is excessive, a groove spiraled to pump oil back up will help, Fig. 28b. Horizontal collar thrust bearings should be lubricated by oil introduced somewhere along the top, where there is neither journal pressure or thrust pressure, Fig. 24. Annular holes drilled through the cap lead to the small diameter between the thrust collars, not to the collars themselves, where oil would be thrown outward. Oil is led through radial grooves in the babbitt along the sides of the collar.

The crankpin bearing works under reversing pressure, hence requires no grooving. Some authorities argue that the pin itself should be grooved, the

radial hole carrying oil from the pin core to the surface opening just ahead of the pressure area when the pin is on either dead center. A longitudinal groove there, Fig. 26, helps oil to be distributed along the width of the brass on the side away from pressure. Compressor crankpins and eccentric bearings reverse this, because the pin drives the rod, so the oil hole must emerge on the opposite side. Automotive piston rods have a single annular groove at the center.

Reciprocating or flat curved surfaces, such as slippers on crossheads, can be lubricated by several oil holes, or perhaps one hole, connected by diamond-shaped grooves, Fig. 27. Shoe ends must be chamfered to create wedge action in pulling oil under the slipper.

Large flat surfaces requiring grooving are grooved in accordance with principles given here for bearings. Such surfaces are rare in power plants. Reciprocating elements such as diesel pistons and fuel-pump plungers require quite different methods of oil distribution. The fuel-pump plunger, tightly fitted, usually has a single annular ring about its center, which collects a shot of oil each time the groove is aligned with an oil-delivery hole. The piston may be lubricated by timed shots between the first and second rings at bottom dead center, or by the splash system. Many diesels have special hand- or motor-driven lubricating-oil pumps which build up oil pressure before the unit is started, thus avoiding extreme starting wear in cylinder walls and wristpins.

Grease—Man first lubricated skids and axles by rubbing them with a chunk of suet—good while it lasts, but soon wearing off. Then the only lubricant is the thin film adhering to the surface. We haven't improved a bit on that method when we use paddle, swab or brush to lubricate axles, open chains, wire ropes and open bearings. Our first improvement is the grease cup, Fig. 29, preferably with sloping bottom, which forces grease from the outlet each time the cap is screwed down a turn or two. Caps must fit tightly, or have leather gaskets, to avoid leakage, and the cap may back up under pressure unless a catch pawl, Fig. 30, is put in. Another step forward is the compression grease cup, in which a spring-loaded plunger maintains steady pressure on the grease, Fig. 31. No. 1 and 2 greases can be fed this way. For harder greases, the crankpin type, Fig. 32, must be used. When milled collar 1 is turned down, increasing compression forces grease up into small cylinder 2, raising the piston against a strong spring. This maintains pressure until indicator 3 drops down to show more feed must be given. Another variation, Fig. 33, utilizes compressed air to force out lubricant. Grease is put into space 1, then cap 2 is screwed down tightly, creating air pressure below disk 4 (disk 3 just keeps the grease level). Locknut 5 holds the cap tightly, and air pressure feeds the grease. If bearing temperature rises, heat is conducted through the center funnel, softening the grease and increasing air pressure to increase feed. Other types, on moving parts, use centrifugal force to feed the grease.

Rises in temperature cause more grease to flow, because it softens, and thus may waste grease, but the cup of Fig. 34, requires heat to operate at all. It works like a bottle oiler, the needle conducting heat from the bearing up to melt grease.

Similar to the compression cup is the grease-packed bearing, Fig. 35, in which a block of hard grease is laid on top of an open-topped or open-sided bearing. Rubbing of the shaft melts and takes off a little grease. Sometimes soft grease is used instead, in a wool-yarn "nest." Anti-friction bearings, however, are often grease-packed, keeping out dust and dirt, avoiding leakage and waste, and requiring attention only at long intervals. Very light greases are used, heavier ones might cake.

Higher-speed machines have fittings for pressure guns similar to pressure-type oil guns of Fig. 3. Typical fittings are shown in Fig. 36. Guns produce a pressure as high as 10,000 lb. per sq. in., forcing out old grease and with it grit and dirt. These require frequent application. There are also pump systems.

Hard greases, usually the white variety, are fed in large rolling-mill and colliery engine crankpins through mechanical lubricators much like banjo oilers and other mechanical oiling arrangements. A rachet and pawl force a plunger down on the grease, and are actuated by a lever fastened to a reciprocating element or by a weighted lever arm which swings back and forth like a pendulum. Such a lubricator delivers grease uniformly regardless of temperature variations, and can be adjusted over a small range by changing length of the lever arm or pendulum-weight position.

Solid Lubricants—Most solid lubricants are applied simply by bumping a "pounce" or porous bag full against the surface. Graphite, however is sometimes fed by a special squirt can. Graphite is also used in "oil-less" bearings, and often applied mixed with grease for convenience. If solid lubricants are mixed with oil, there is danger that they will separate out and clog oil passages. Graphite is never used in first-class ball and roller bearings except in colloidal form. A new foreign arrangement forces graphite into a steam line with a pressure pump and an atomizer, Fig. 38.

For more detailed descriptions of various lubrication devices, see manufacturers literature and bulletins, page 330.

Fig.29-Simple Grease Cup

Fig.30-Ratchet Type

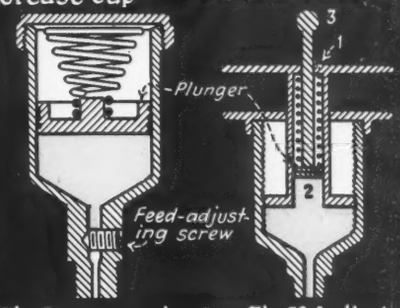


Fig.31-Compression Cup

Fig.32-Indicator Cup

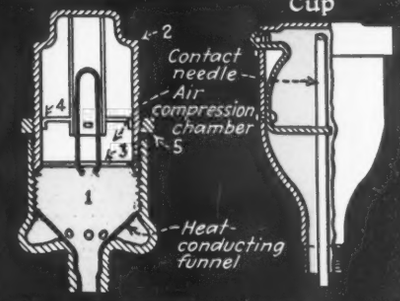


Fig.33-Pneumatic Cup

Fig.34-Thermal Cup

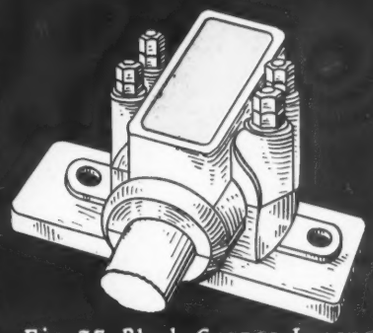


Fig.35-Block-Grease Journal

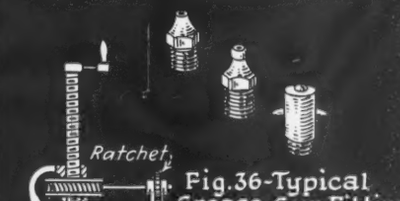


Fig.36-Typical Grease-Gun Fittings

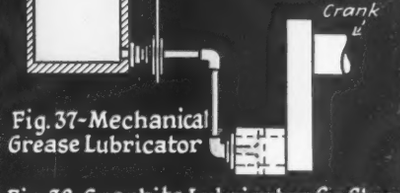
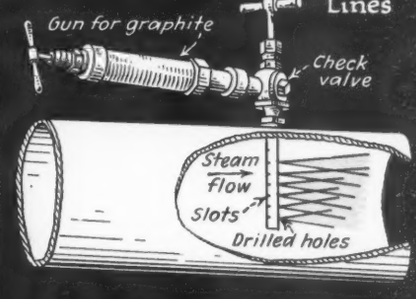


Fig.37-Mechanical Grease Lubricator

Fig.38-Graphite Lubricator for Steam Lines



How To Choose

• You, as a power engineer, have equipment incorporating more lubrication problems than are found anywhere else. Journal and anti-friction bearings may face extremely high or low speeds and temperatures, constant or intermittent loads; cylinders may have the high temperatures of diesels or the low ones of refrigeration. Each application requires a different lubricant; many require two or more.

Steam Engines—Internal lubrication includes cylinder walls, pistons, valves, etc., and is the difficult problem; external lubrication, such as on bearings, is much simpler. Steam quality, engine load, use made of exhaust and type of engine all influence the kind of cylinder oil selected. In general, where exhaust is not used directly, a compounded oil (3–10% of animal or vegetable fat) is best, the percentage of organic fat increasing with the amount of moisture in the steam so that the oil forms an emulsion which clings to lubricated parts. If the exhaust is superheated, heats water directly, or is used in process, straight mineral oil, which separates out more easily, may be required.

Table I shows general recommendations of a large oil company. In all cases, a compounded oil is indicated for steam cylinders. A good cylinder oil should have a S.U. viscosity of 130 to 150 at 210 F; flash point, 540 to 600 F; and fire point 600 to 680 F. The oil must emulsify readily, have high resistance to oxidation, have high viscosity and flash point, and atomize readily so it is carried into contact with mating surfaces. Local conditions, such as grade of oil, moisture in steam, degree of superheat, boiler feedwater treatment, allowable exhaust oil content, all affect the amount of cylinder lubrication used. Table II gives general recommendations of one engine company, usable only as an approximate guide.

TABLE I—GENERAL CHARACTERISTICS OF LUBRICATING OILS FOR VARIOUS SERVICES

TYPE OF UNIT	OPERATING CONDITIONS	[1] Kind of Oil	[2] Ease of Emulsion	[1] Resistance to Oxidation	[2] Viscosity	[1] Flash	[1] Carbon Content
Steam Engine	100 lb., wet steam, any load	C	E	M	L	H	
	100 to 150 lb. superheated, dry or wet steam, any load	C	E	H	M	H	
	[3] Above 150 lb., superheated steam, any engine load	C	M	H	H	H	
	Above 150 lb. dry steam, 0 to 50% load	C	E	H	M	H	
	Above 150 lb. dry steam, 50 to 100% load	C	M	H	H	H	
			[1] Ease of Demulsibility				
Steam-Engine Bearings	Any speed, hand or drop system	Mi	G	G	M	H	
	Any speed, circulating system	Mi	E	H	M	H	
	Speed over 100 r.p.m., splash system	Mi	E	H	L	H	
Direct-Connected Turbines	Circulating lubricating systems	Mi	E	H	L	H	
	Ring Oil Bearings:						
	Temp. below 140 F	Mi	E	H	L	H	
	Temp. 140 to 200 F	Mi	E	H	MH	H	
	Temp. above 200 F	Mi	E	H	H	H	
Geared Turbines	Circulating system supplying gear and turbine	Mi	E	H	M	H	
	Separate Lube System for Gears:						
	Temp. below 140 deg. F	Mi	E	H	M	H	
	Temp. above 140 deg. F	Mi	E	H	MH	H	
Diesel Engines	4-Cycle, and Pump-Scavenging, 2-Cycle Engines:						
	Up to 150 hp. per cylinder. Same lube for cylinder and bearings	Mi		H	MH	H	L
	Bearings separate circulating system	Mi		H	M	H	L
	Bearings ring or collar oiled	Mi		H	MH	H	L
	150 to 350 hp. per cyl., cylinder lube	Mi		H	H	H	L
	Bearings and oil-cooled pistons	Mi		H	MH	H	L
	Over 350 hp. per cyl., cylinder lube	Mi		H	VH	H	L
	Bearings	Mi		H	MH	H	L
	Crankcase scavenging 2-cycle	Mi		H	MH	H	VL
	Horizontal Engines:						
	Cylinders	Mi		H	LM	H	L
	Bearings, circulating system or mech. lub.	Mi	E	H	M	H	
	Bearings, drop feed	Mi	E	H	MH	H	
	Water-Injection Engines:						
	Cylinders	C		G	MH	H	L
	Air-injection engines, 3-stage air compressors	C		H	MH	H	L
Air Compressors	For Cylinders or Where Same Lubricant is Used for Cylinders and Bearings:						
	Number of Stages / Delivery Pres. Lb. per Sq. In.						
	Single ... Up to 85	Mi	E	H	LM	H	L
	Single ... Above 85	Mi	E	H	M	H	L
	Multiple ... Up to 225	Mi	E	H	M	H	L
	Multiple ... Above 225	Mi	E	H	MH	H	L
	Multiple with moist conditions Above 800	C		H	MH	H	L
	Large units with no tailrod	Mi	E	H	H	H	L
Air-Compressor Bearings	Pressure Circulating Systems:						
	Up to 300 r.p.m., 32 to 140 F	Mi	E	H	LM	H	L
	" " above 140 F	Mi	E	H	M	H	L
	Above 300 r.p.m. 32 to 140 F	Mi	E	H	L	H	L
	" " above 140 F	Mi	E	H	LM	H	L
	Splash, Ring or Chain Oiling:						
	Up to 300 r.p.m., 32 to 140 F	Mi	E	H	M	H	L
	" " above 140 F	Mi	E	H	MH	H	L
	Above 300 r.p.m., 32 to 140 F	Mi	E	H	LM	H	L
	" " above 140 F	Mi	E	H	MH	H	L
Rotary Compressors	Internal parts	Mi	E	H	M	H	L
	Bearings	Same as for other compressors					[1] Pour
Refrigeration Compressors	Ammonia and carbon-dioxide	Mi	F	H	LM	H	L
	Methyl-chloride and ethyl-chloride	Mi	E	H	LM	H	L
	Sulphur dioxide	W	E	H	LM	H	L
	Freon	Mi	E	H	LM	H	L
	Propane	Mi	E	H	LM	H	L

[1] Symbols: *C*, compound; *E*, excellent; *G*, good; *H*, high; *L*, low; *M*, medium; *Mi*, mineral; *W*, white.
[2] In the viscosity column, symbols are arranged in an ascending scale, beginning with *VL*, very low, with a viscosity of around 100 at 100 F., followed by *L*, low; *LM*, low medium; *M*, medium; *M+*; *MH*, medium high; *H−*; *H*, high; *H+*; *EH*, extra high; *VH*, very high; *SH*, super high, with a viscosity of around 155 at 210 F.
[3] For pressures above 150 lb. and high superheat, a mineral oil may be required.
[4] Light duty indicates low tooth pressure at medium or high pitch-line speeds; moderate duty, medium tooth pressure and pitch-line speed; and heavy duty, high tooth pressure, variable loads, reversing service and shock loads.

(Table I — Continued on next page)

Table II — Approximate Quantity of Steam-Cylinder Lubricant

ENGINE SIZE	PINTS OF OIL FOR 8-HR. RUN
Up to 100 i.hp.	1.5 to 2
150 to 250 i.hp.	2 to 4
300 to 500 i.hp.	3 to 5
600 to 1,250 i.hp.	4 to 6

For steam-engine bearings, Table I, the lubricant should be good-grade mineral oil of medium or low viscosity, depending upon method of application. It should have high demulsibility (separate readily from water). Parts such as eccentric straps and governor and valve-gear bearings are greased through compression cups, although some engines have pressure fittings.

Turbines—Two systems, pressure-circulating and ring-oiling, Table I, are employed for lubricating steam-turbine (and usually driven-unit) bearings, the former on large and some small units, the latter on small units for lower first cost. Ring oiling normally requires a higher-viscosity oil, because it gets hotter than that used in pressure-circulating systems incorporating external oil coolers.

Turbine oils must have high demulsibility and high resistance to oxidation (which creates asphaltic and organic-acid precipitates that form sludge with water). One make of turbine oil is now guaranteed for the life of the turbine, provided the oil system is initially clean, oil temperatures are held below 170 F, and only the same oil is used in replenishment.

Diesels—Lubricants must resist high temperatures and pressures of over 500 lb. per sq. in. which tend to force piston rings against the cylinder wall and thus squeeze out the oil film. The film must also seal against blowby. Size of engine, speed, type, etc., influence oil selection. The larger a cylinder, the higher its surface temperature, hence the higher the viscosity required in its lubricant, as well as higher flash point and resistance to oxidation, but lower carbon content. Bearing lubrication is somewhat easier. If a separate system is used, a lower-viscosity oil can be used. See Table III.

Table III — Methods of Lubricating Diesel Engines

CYLINDERS	BEARINGS
Mechanical force-feed (no oil throw)	Circulation oiling
Mechanical force-feed	Mechanical force-feed
Mechanical force-feed	Ring or drop-feed oiling
Mechanical force-feed (with oil throw)	Circulation oiling
Oil throw only	Circulation oiling
From circulation system	Circulation oiling
Splash	Splash

Air Compressors — Temperatures are not quite as high, and flame is not present, but otherwise air-compressor cylinder lubrication is similar to that on diesels. Air filters are essential, oil selection must be exact, and feed must not be too great (extra oil carbonizes and creates danger of explosion).

Other Equipment—In Table I, more important qualities of a lubricant for various services are in qualitative rather than quantitative terms. Equipment manufacturers and oil companies will give detailed advice.

Greases—are not normally as good lubricants as oils, tend to separate under high temperatures and speeds, and offer greater frictional resistance. But they are better in dirty atmospheres because they seal bearing ends and carry dirt and grit out, require less attention in difficult-to-reach and sometimes-neglected bearings, insure some lubrication due to permeation of rubbing surfaces and film adherence even after the mass of grease is gone, have less tendency to drip or spatter, lubricate worn bearings or surfaces better (particularly with graphite), and are superior in severe conditions such as high temperatures, extreme pressures, low speeds, shock loads, intermittent operation, etc.

Selection is complicated, usually requiring the services of a specialist and purchase according to a specification. Some general characteristics may, however, be given here. Lime-base greases (usually 70–90% mineral oil) should not be used for temperatures above 175 F, nor under high speeds or churning. They are not suitable for anti-friction bearings under high speeds and high temperature, but are water-repellent. Sodium-base greases, which do not contain water as a binder, are suitable for high speed and temperature, but emulsify readily with water. They can be used in anti-friction bearings at high speed and temperature, in plain bearings, and centralized-pressure lubrication systems.

Aluminum-base greases combine some of the advantages of the two types above. They are water-repellent, withstand high temperatures, do not separate when agitated or used in centralized-pressure systems. They are non-spattering, and can be applied with a grease gun where operating temperatures and pressures are high. Lead-base greases are "extreme-pressure" lubricants, do not emulsify or dissolve in water (but do settle out in water containing some mineral oil), and are sometimes used in transmission greases. Zinc-base greases are water-repellent, hence often called "hydraulic greases" and used to lubricate hydraulic-elevator plungers, hydraulic-turbine gates, water-pump piston rods, and as slushing compounds. Mixed-base greases combine to some degree characteristics of the soaps in the mixture.

According to consistency, greases are classified from 0 to 5, 0 being fluid, 1 very soft, 2 soft, 3 medium, 4 hard, and 5 very hard. Fluid greases are the "solidified," "dripless" or "non-spattering" types, made of mineral oil thickened with less than 5% aluminum soap. Use them on speed reducers, cranes, etc. No. 1 greases are preferable where temperatures are lower and speeds higher than for No. 2. The latter are used on light-duty shafts, ball and roller bearings, gearboxes, and general applications using grease cups and guns. No. 3 includes general-purpose greases for slightly heavier machinery, No. 4 for heavy duty in coal conveyors, cranes, etc. No. 5 greases may have melting points that range up to around 450 F.

TABLE I (CONTINUED)—GENERAL CHARACTERISTICS OF LUBRICATING OILS FOR VARIOUS SERVICES

Motor and Generator Journal Bearings:

BEARING CONDITIONS: SPEED R.P.M. Below 300	300–2,000	Above 2,000	TEMPERATURE, DEG. F. Below 32	32–140	140–200	Above 200	OILING SYSTEM Ring or Bath	Drop, Wick or Waste-Packed	Hand	Pressure	[1] Kind of Oil	[1] Ease of Demulsibility	[1] Resistance of Oxidation	[2] Viscosity	[1] Flash	[1] Pour
X	X	X	X				X	X	X		Mi	E	H	LM	H	L
X				X			X	X	X		Mi	E	H	M	H	M
	X			X			X	X	X		Mi	E	H	LM	H	M
	X			X						X	Mi	E	H	L	H	M
		X		X			X	X		X	Mi	E	H	VL	H	M
X					X		X	X	X		Mi	E	H	MH	H	M
	X				X		X	X	X		Mi	E	H	M	H	M
		X			X		X	X		X	Mi	E	H	L	H	M
X						X	X	X	X		Mi	E	H	VH	H	M
	X					X	X	X	X	X	Mi	E	H	H	H	M
		X				X	X	X	X	X	Mi	E	H	MH	H	M

Ball and Roller Bearings:

X	X	X	X								Mi	E	H	LM	H	L
X				X							Mi	E	H	M	H	M
	X			X							Mi	E	H	L	H	M
		X		X							Mi	E	H	VL	H	M
X					X						Mi	E	H	VH	H	M
		X			X						Mi	E	H	M	H	M
		X			X						Mi	E	H	M	H	M

Enclosed Gears; Spur, Helical, Bevel and Herringbone:

[4] DUTY Light	Moderate	Heavy	LUBRICATING SERVICE Gears and Bearings	Gears Only	LUBRICATING METHOD Circulation	Splash					
X			X		X		Mi	E	H	M	H
	X		X		X		Mi	E	H	M+	H
		X	X		X		Mi	E	H	MH	H
X				X	X		Mi	E	H	M+	H
	X			X	X		Mi	E	H	MH	H
		X		X	X		Mi	E	H	H	H
X			X			X	Mi	E	H	MH	H
	X		X			X	Mi	E	H	H−	H
		X	X			X	Mi	E	H	EH	H
X				X		X	Mi	E	H	H−	H
	X			X		X	Mi	E	H	EH	H
		X		X		X	Mi	E	H	VH	H

Enclosed Gears; Worm, Spiral, Skew and Hypoid:

X			X		X		Mi	E	H	M+	H
	X		X		X		Mi	E	H	MH	H
		X	X		X		Mi	E	H	H	H
X				X	X		Mi	E	H	MH	H
	X			X	X		Mi	E	H	H−	H
		X		X	X		Mi	E	H	EH	H
X			X			X	Mi	E	H	MH	H
	X		X			X	Mi	E	H	EH	H
		X	X			X	Mi	E	H	VH	H
X				X		X	Mi	E	H	EH	H
	X			X		X	Mi	E	H	VH	H
		X		X		X	Mi	E	H	SH	H

[1] Symbols: *C*, compounds; *E*, excellent; *G*, good, *H*, high; *L*, low; *M*, medium; *Mi*, mineral; *W*, white.
[2] In the viscosity column, symbols are arranged in an ascending scale, beginning with *VL*, very low, with a viscosity of around 100 at 100 F., followed by *L*, low; *LM*, low medium; *M*, medium; *M+*; *MH*, medium high; *H−*; *H*, high; *H+*; *EH*, extra high; *VH*, very high; *SH*, super high, with a viscosity of around 155 at 210 F.
[3] For pressures above 150 lb. and high superheat a mineral oil may be required.
[4] Light duty indicates low tooth pressure at medium or high pitch-line speeds; moderate duty, medium tooth pressure and pitch-line speed; and heavy duty, high tooth pressure, variable loads, reversing service and shock loads.

BIBLIOGRAPHY

AMONG fairly recent books on lubrication are: "Practice of Lubrication", (McGraw-Hill) by T. C. Thomson; "Power-Plant Lubrication", (McGraw-Hill), by W. F. Osborne, and "American Lubricants" (Chemical Pub. Co.), by L. B. Lockhart. Although all these are now several years old, they provide basic data on the subject. Newer, but much more technical, texts include 'Theory of Lubrication" (John Wiley), by M. D. Hersey, and "Chemical Refining of Petroleum" (Chemical Pub. Co.), by V. A. Kalechevsky and M. A. Stagner.

American Society for Testing Materials has various bulletins and standards on lubricants, as does the Bureau of Engineering, U. S. Navy Dept. Prof. Clower, who has written a comprehensive series of articals in recent numbers of POWER, has also written two bulletins for Virginia Polytechnic Institute, "American Lubricating Greases", and "Lubricating Oil Tests" that are distinctly helpful. Prof. Clower's articles have appeared regularly in POWER during the past three years, and there have also been many others, including the series on compressor lubrication by Ezra K. Nicholson. POWER also published a booklet, "Lubrication in the Power Plant", some time ago. The A.S.M.E. and other engineering societies have published many excellent papers on lubrication research and practice.

Practically all nationally known lubricant manufacturers have published elaborate catalogs, technical bulletins and monographs on various phases of the lubrication problem, many excellently illustrated and extremely detailed. An excellent basic job is the 3-part "Panorama of Lubrication", just published by Shell Petroleum Corp., which suggested several of the illustrations in this section. "Lube-text" of Standard Oil Co. of N. J. also gives much basic information as well as more detailed data.

More specialized data are included in the monthly magazine "Lubrication" of the Texas Co., "Engineering Bulletins" of the Standard Oil Co. of Ind., a whole series of pamphlets by Socony-Vacuum Oil Co., Inc., "Oil Ways" of Standard Oil Co. of N. J., "Lubrication of Bearings" of The Pure Oil Co. and pamphlets of Tidewater Oil Co. and Gulf Refining co.

Other lubrication material found helpful in preparation of this section include "Research Illustrated" and "The Houghton Line" of E. F. Houghton & Co.; "The Lubriplate Film", by Fiske Bros. Refining Co.; catalog sections on "Gredag" lubricants, by National Carbon Co., Inc.; "Controlled Lubrication", by Alemite Division of Borg-Warner Corp.; pamphlets of Dixon Crucible Co., and a number of others.

General and specific data on lubrication can be obtained from any of the oil companies on application. A fairly complete list of lubricant manufacturers appears in the Diesel Section of this number of POWER, immediately following, and also includes the names of makers of oil-reclaiming, centrifuging and filtering equipment.

Trouble Shooting

• The best way to avoid trouble is to prevent it. Proper storage and handling (page 332), proper cleaning and reclaiming (page 331), proper selection (page 328), proper methods (page 324)—all these play their part.

If bearings heat up, are oiling devices, containers, grooves, clean? Is oil of proper characteristics being supplied in sufficient quantity? Have load conditions changed so that a different lubricant is necessary? Is the bearing so worn it can no longer retain a lubricant, or so tight the lubricant can't get in? In a brass bearing, is oil escaping between housing and brass? Is the brass warped from overheating or from sudden cooling with water? Is it cracked or rough? Is babbitt cracked or too tight? Are feed pipes choked? Are bearings so long they should have additional openings for lubrications? Is bearing pressure upward instead of downward, requiring lubrication from side or bottom instead of top? In splash-oiled bearings, is oil level too low, or has water emulsified the oil?

Have you been using cotton rags or waste instead of wool or silk and thus gotten lint into the bearing? Have you mixed mineral oil with a compounded oil? (If the latter contains a lot of blown vegetable oil, the fresh oil will cause it to throw down a sludge.) If it is the crankpin bearing on a steam engine, it may be light load, which admits too little steam to the cylinder to cushion the piston. Belts or rope drives that are too tight, equipment out of alignment, and vibration due to unbalance are all very important—any one can cause more trouble than the wrong lubricant.

Hot bearings are among the most important troubles, because if not treated promptly, they result in seizure or melting out of babbitt. They are evidenced by heat, the smell of hot oil, or by pounding. A hot crankpin or main bearing has a dull or heavy thump just after the crank passes dead center, the main bearing giving the duller noise and causing the shaft to jump. A crosshead knock is sharper, but not so audible. Often, a machine cannot be stopped immediately. In that case, see if the bearing is oil starved, and if so increase oil supply. Use a heavier, more viscous oil. Loosen cap nuts slightly. Possibly a little fixed oil, like castor or rape, added to viscous mineral oil may reduce temperature by producing a better film, but don't use it if the bearing is part of a circulating system, because this compound may cause the system oil to sludge. If rubbing surfaces appear seriously abraded, add a little graphite, not more than 3-4% of flake or 0.35% of colloidal—more just increases friction. If clearance spaces are very small, flake will usually be better. Don't use graphite in a ball or roller bearing, and be careful that the graphite is kept agitated, otherwise it may precipitate and clog oil passages. Acid-treated oils increase this tendency.

Graphite fills pits and rough spots created by abrasion, thus is helpful in starting. Bearings tending to run hot (and worm gears) can often be kept lower in temperature by periodic additions of graphite to the lubricant. On large bearings which heat up, some engineers use flowers of sulphur or white lead. These mild abrasives actually grind down rough spots, then are flushed out with plenty of viscous oil. Even brick dust, grindstone dust or salt have been used on large slow-speed bearings in emergency—they act like flowers of sulphur on a larger scale. Hard solid lubricants like talc or mica are of doubtful value, and may increase friction instead of reducing it. Remember that graphite stains hands, and materials in process. Graphite alone is suitable for lock tumblers and close-fitting small parts, and parts likely to be neglected which run at heavy duty and low speeds. Mixed with grease, it is suitable for parts at low pressures and speeds. The graphite separates from the grease and coats the mating parts.

In a steam engine, insufficient internal lubrication causes groaning noises, vibration of valve rods and other parts, and sluggish closing of corliss valves. If an engine is light-loaded most of the time, use a lubricant with more compounding. If normal lubrication fails, don't just increase the feed; find out what's wrong. If an oil is to be used only once, a lower quality may be justified than if it is recirculated. In general though, high-cost lubricants are low-cost insurance against excessive maintenance and unreliable operation.

Worn motor and generator bearings cause the rotor to rub, thus causing more wear and heating. Excessive oiling, leaks or wear cause oil throwing, deteriorating insulation, picking up dust and clogging ventilating passages, and causing sparking on the commutator. Be sure the shaft is level and that armature and end pieces are in line. Misalignment causes endwise pull that heats bearings. Diesel crankshafts must have endplay for the same reasons, particularly if connected to a generator.

In all lubrication problems, authority is far better than cut-and-try. The bibliography lists many good pamphlets and bulletins summarizing years of experience. They will often prove the ounce of prevention that outweighs many pounds of cure.

To Clean An Oil . . .

• Egyptians, 3600 years ago, used animal fats for lubricants. Each drop of oil worked once, then was lost. We instead conserve our supply in many cases by using the same oil over and over again. That means that it must be cleaned, for just in handling and storing it, we're likely to get dirt in it. In service, oil picks up dust particles from the air or from lubricated parts; water or other liquids get in; steam condenses in it. If it is exposed to considerable heat, some may burn, producing carbon that contaminates it.

Impurities may be gaseous, liquid or solid. Air may provide the oxygen that makes hot oil carbonize; water may form an emulsion that collects burned particles to form sludge, tiny particles of dust or metal may be scraped from lubricated areas. The proper oil for the job will avoid some trouble; careful use and handling will avoid more, but eventually, any re-used oil must be cleaned.

There are three methods of cleaning: batch, continuous, and combination. In batch treatment, all oil is withdrawn from the system, preferably while hot, and allowed to settle for ten days or more in a tank. Water and other insoluble impurities settle out, and the oil can then be purified by filtering or centrifuging. In the continuous treatment, all or part (called "bypass") of the oil is cleaned as it circulates, by passing it through a gravity, pressure or centrifugal purifier. It is usually drawn from the bottom of the reservoir, where impurities settle, and is returned directly to the system after cleaning. Combination cleaning usually combines the batch and bypass methods. Part of the oil is bypassed for cleaning during service, to retard oxidation and emulsification. Then, periodically, the whole batch is withdrawn for cleaning while the system itself is cleaned—just as you do in your automobile crankcase. One good time for batch treatment is during an overhaul or check-up.

There are a wide variety of equipments and systems for reconditioning (see *Power* for Nov., 1936, and for Jan., Mar., and May, 1937). The arrangement you select depends upon operating conditions, equipment, kind of lubricant, size of plant, etc. Here are some factors:

Batch settling takes time, requires two complete batches of oil, space for settling tanks, and usually that the machine be shut down for withdrawal. It does not *keep* impurities down (because they build up to some predetermined concentration before purification). Equipment is quite simple, the process can be speeded up by heating the oil (with exhaust gas or steam), it will work on any mineral oil, and withdrawals can be made when the machine is shut down for other reasons.

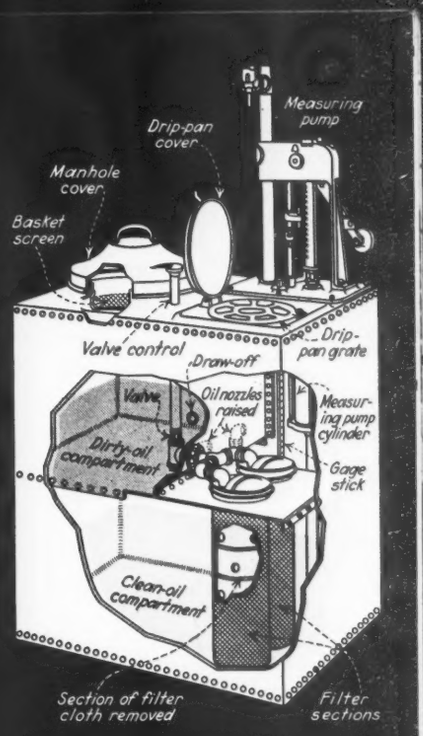
Continuous cleaning may use only a screen, but that will not remove acid or water or all of the fine dust or insoluble sludge particles. Equipment to do the whole job is usually large, cost may be out of proportion to savings, and only a small proportion of soluble products of oxidation are removed. Small, high-capacity pressure filters overcome the first two objections. The bypass system, cleaning only about 10% of the oil per cycle, is much smaller and costs less, but doesn't clean as well.

Pressure or vacuum filters differ only in placing of the circulating pump. Some have cloth bags (wool with high-sulphur oils, linen or cotton for best filtration), some metal elements (cleaned by scraping) in the form of a coil or a stack of disks, still others have Fuller's earth cylinders or stacks of paper disks (between which oil passes—cleaned by scraping, reverse flow, or by air under pressure). They may have electrical, steam, jacket water, or exhaust-gas heating coils.

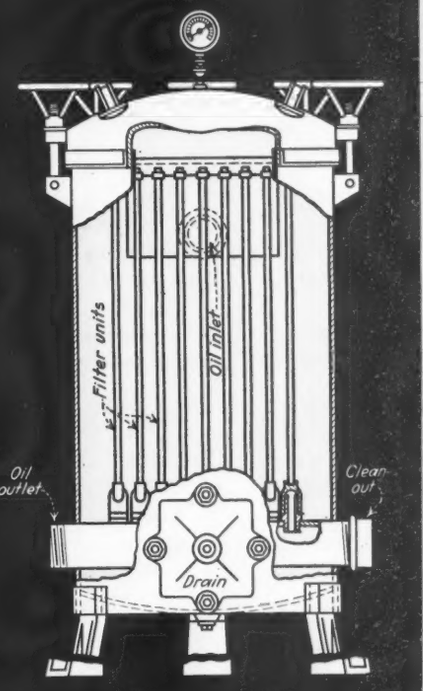
Gravity Units

Gravity units screen, precipitate, filter and sometimes wash with water, all in one unit. Screening is first, to remove coarse solids, followed by settling, to take out water and heavier insoluble impurities. Heating speeds the operation, but reduces quality of cleaning. The final operation is screening again, this time with cotton waste, wood wool, excelsior, felt, cloth, etc., arranged to give large area and slow flow and to permit elements to be removed for cleaning one at a time. Such units will clean any oil wherever space is available, oil is supplied at low pressure, and there is no rolling or pitching (not suitable for force-feed, automotive or steamship use).

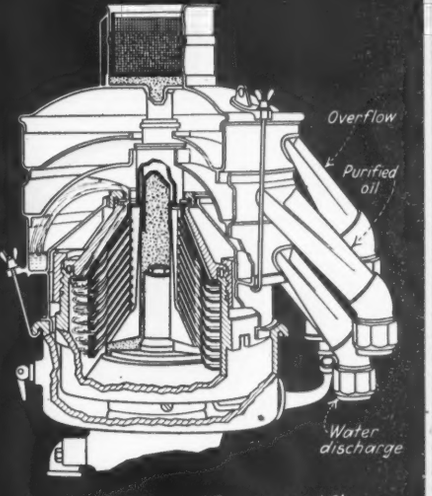
Centrifugal purifiers are basically precipitators, but work faster. The difference in specific gravities causes oil to separate from impurities and they are then forced off. Capacity varies with viscosity, temperature, kind of impurities, persistency of emulsion (if water is present), and purification desired. If the oil is heated before centrifuging, the capacity goes up. These units can be used simply to remove solid impurities, or to take out both solids and water, as desired. They will not remove colloidal carbon or soluble sludge, kerosene or other diluents, nor do they affect viscosity, flash and fire points and color. Details of these units appeared in May *Power*, pages 248-250.



Small, special gravity purifier for crankcase oil



Multiple-bag pressure filter (Bags may be fabric or Monel gauze)



Bowl of a centrifugal purifier

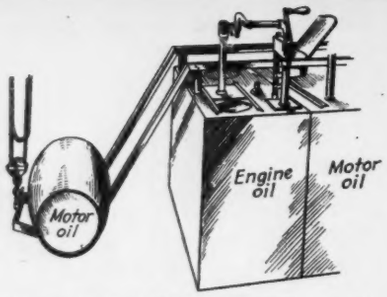


Fig.1-Rig for Filling Battery of Storage Tanks from Barrels

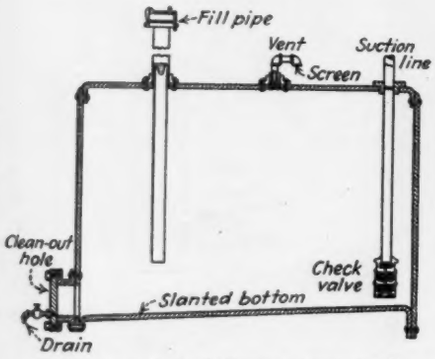


Fig.2-A Good Storage-Tank Design

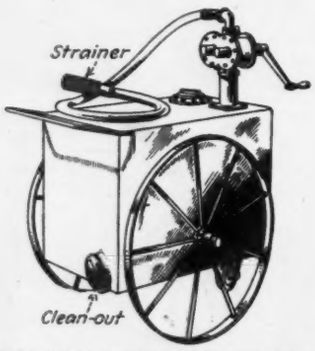


Fig.3-Portable Tank with 2-Way Pump
(Pumps from barrel, then into machine or dispensing tank)

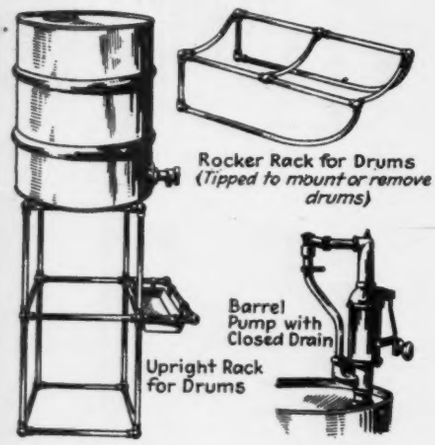


Fig.4-Various Oil-Dispensing Methods

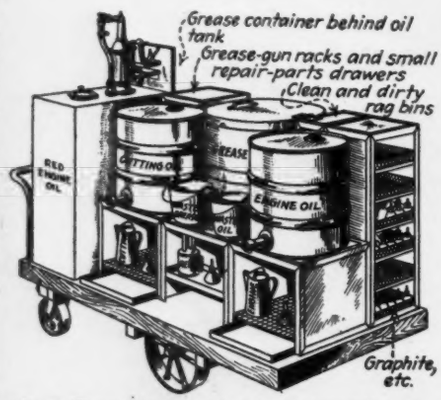


Fig.5-Portable Oil and Grease Truck

Storing and Handling

• The finest cake ever baked isn't worth eating after two weeks of exhibition in the baker's window, and the finest oil ever refined is useless if it is stored and handled carelessly. Even a little dirt and contamination will impair the lubricating qualities of an oil or a grease and take its toll in excessive wear, loss of power, perhaps even shutdowns. Storage in too hot or too cold a place, exposure to weather, or transfer into contaminated containers also spoil a lubricant.

The refiner stores lubricants carefully, ships them in clean drums, barrels, or individual containers, and delivers them clean. But if you, as the user, don't follow suit, all his precautions are useless.

First, store oil in clean containers, cleaned since the last batch of oil was drained from them. Larger tanks can be sheet iron or sheet steel. Don't use galvanized iron—the zinc is likely to react with oils, particularly if they are compounded. Tankcar-size storage tanks are economical, if the type of lubricant, amount you use a day and a year, available space, and heating method (for cold-weather unloading) are correct. If you use much oil, frequent barrel or drum purchases may be the sensible thing. Either fill or empty big storage tanks by gravity; pumping on both sides is not economical. Keep heating coils in single lengths (to avoid connections), and near the outlet, and do not heat oil above 70 to 100 F. If possible, the tank should be indoors, to avoid excess breathing in cold weather, extremely high or low temperatures, and other undesirable effects.

Keep barrels inside on their sides, to avoid obliteration of brand names, collecting of dirt and moisture on the head, and breathing, with its resulting contamination. Keep stocks small, and always use the oldest oil first. Keep waste, rags, etc., in metal containers, and have a fire extinguisher or two handy. Elevate a barrel of new lubricant over storage tanks as shown in Fig. 1, or pump it over, either directly or with air pressure.

To avoid mixing of different grades of oil, have all tanks plainly lettered, and also if possible, marked with different and well-understood colors, preferably with a chart explaining them posted at the tanks. A simple thing like good lighting often will do more to avoid mistakes than anything else.

All oil containers should have vents, to take care of breathing, away from dirt and moisture-laden air. Even with such precautions, a tank will in time accumulate some moisture and contamination. For that reason, set up storage tanks at a slight slant, with drain plugs at lowest points, Fig. 2. The oil drain normally used should be several inches above the tank bottom, so it will tap clean oil. Clean underground tanks with a suction pump twice a year or oftener. Larger tanks, with manhole openings, can be cleaned by sending a man in, but be sure he has a gas mask, doesn't strike sparks, and that other men are stationed nearby to help him if vapors overcome him. Clean large and small containers regularly by flushing with kerosene, but get it all out before you refill them.

If you use a lot of lubricating oil, connect machines to a central storage, but be sure lines are clean and free of sediment. Otherwise, use a wheeled truck like that in Fig. 3.

In the power plant, have the oil stored near the machines, so operators do not waste a lot of time going back and forth—it may mean postponement of refilling until the last minute and insufficient lubrication. If you have many kinds of lubricants, keep them in a separate oil room; otherwise, use barrel-type dispensers with pumps controllable so they do not pump out a lot of excess oil which goes back into the barrel, carrying incidental dirt with it. Barrels should be kept warm, or allowed to warm before being tapped—otherwise you won't know what you're getting. Fig. 4 shows several types of oil dispensers.

For general machine oiling, supply the oiler with a small truck like that in Fig. 5, with tanks for most-used lubricants and racks for bottles of others. Provide racks for grease guns and containers for waste and rags. Tools and a supply of wick feeds, grease and oil cups, etc., are carried in drawers.

Grease Container

Keep grease barrels or containers tightly covered except when grease is being removed, and give each container its own clean paddle. Fill grease guns in the oil room, or if it must be done on the job, fill from a grease container with a filling attachment. Clean grease cups and pressure fittings before refilling them and keep dirt out as they are reclosed.

Last, and probably most important, keep adquate records so you know how much lubricant is being used of each type, where it is used, how it is being used. Have a definite routine with well thought-out instructions so that no man has an excuse for not oiling any part with the proper lubricant. Inspect equipment regularly, and see that filtration and reclamation equipment is in working order and being used. Check to see that lubricating devices are correct, with proper lubricants in them. If you aren't sure yourself, call in the oil company's specialist—that's his job.

POWER Special Section No. 14

Twice as large as any previous compilation, this fifth of POWER's annual lists of typical stationary plants includes 490 engines in 365 installations, reflecting improved business conditions and the rise of the diesel

INSTALLATIONS

Compiled by E. J. Tangerman and B. E. Sawyer
Managing Editor *Assistant Editor*

Owner	Location	Service	Equipt. Driven	Engine Builder	No. Units	Horsepower Each	Speed R.P.M.	No. Cyl.	Cyl. Bore	Cyl. Stroke	Cycle	Starting Method	Fuel Injection	Fuel Consump. lb. per hp. hr.
Grand Haven	Michigan	Mun. Add.	Gen.	Nor	1	2,250	225	6	21	29	2	A	S	....
Ponca City	Oklahoma	Mun. Pwr.	Gen.	Nor	1	2,250	225	6	21	29	2	A	A	....
Logan City	Utah	Mun. Add.	Gen.	Nor	1	2,250	225	6	21	29	2	A	A	....
San Antonio Portland Cement Co	San Antonio, Tex.	Pwr.	Alt.	R-J	1	2,000	225	12	19½	28	4	A	S	0.40
Eastern Shore Pub. Serv. Co	Berlin, Md.	C. S. Pwr.	Gen.	BuS	1	1,666	200	8	17	27	2	A	A	0.43
Russell	Kansas	Mun. Add.	Gen.	DLV	1	1,600	200	8	22	30	4	A	S	....
Potash Co. of America	Carlsbad, N. Mex.	Mining	Gen.	Nor	1	1,500	257	6	17	29	2	A	S	....
Opelousas	Louisiana	Mun. Pwr.	Gen.	BuS	1	1,500	180	8	17	27	2	A	A	0.42
Hudson	Massachusetts	Mun. Add.	Alt.	ALC	1	1,480	277	8	14	23½	2	A	S	0.39
Kansas Power Co	Great Bend, Kan.	C. S. Pwr.	Gen.	FM	1	1,400	300	8	16	20	2	A	S	0.39
Falls City	Nebraska	Mun. Pwr.	Gen.	FM	1	1,400	300	8	16	20	2	A	S	0.39
Litchfield	Minnesota	Mun. Pwr.	Gen.	FM	1	1,400	300	8	16	20	2	A	S	0.39
Rochelle	Illinois	Mun. Pwr.	Gen.	Nor	1	1,250	240	5	17	25	2	A	S	....
Tarboro	N. Carolina	Mun. Pwr.	Gen.	Nor	1	1,250	257	5	17	25	2	A	A	....
Lafayette	Louisiana	Mun. Add.	Gen.	FM	1	1,225	300	7	16	20	2	A	S	0.39
Imp. Valley Irrig. District	Bramley, Calif.	Lt. & Pwr.	Gen.	HOR	3	1,125	240	3	21½	27½	2	A	S	0.39
Barron	Wisconsin	Mun. Pwr.	Gen.	FM	1	1,050	300	6	16	20	2	A	S	0.39
S. W. Public Service Co	Amarillo, Tex.	Pwr.	Gen.	FM	1	1,050	300	6	16	20	2	A	S	0.39
Houma	Louisiana	Mun. Pwr.	Gen.	FM	1	1,050	300	6	16	20	2	A	S	0.39
Anchorage Lt. & Pwr. Co	Anchorage, Alaska	Mun. Pwr.	Alt.	WIW	1	1,000	225	8	18	24	4	A	S	0.40
Cedarburg	Wisconsin	Mun. Pwr.	Gen.	Nor	1	1,000	257	4	17	25	2	A	A	....
Garnett	Kansas	Mun. Pwr.	Gen.	Nor	1	1,000	257	4	17	25	2	A	A	....
Bryan	Texas	Mun. Add.	Gen.	BuS	1	1,000	257	8	16¼	24½	4	A	A	0.41
Stanolind Pipe Line Co	Tulsa, Okla.	Oil	Pump	Nor	2	1,000	225	5	17	25	2	A	S	....
U. S. Engineers	Miss. River	Dredge	Pump	Nor	2	1,000	240	5	17	25	2	A	S	....
New Castle	Indiana	Mun. Add.	Gen.	DLV	1	1,000	240	8	17½	24	4	A	S	....
					1	300	720	6	9	12	4	A	S	....
Denton	Texas	Mun. Add.	Alt.	DLV	1	1,000	240	8	17½	24	4	A	S	....
				ALC	1	1,000	225	8	17½	25	4	A	S	0.39
Jackson	Missouri	Mun. Add.	Alt.	ALC	1	1,000	225	8	17½	25	4	A	S	0.39
R. H. Macy & Co	New York, N. Y.	Pwr. Add.	Gen.	ALC	1	1,000	600	8	12½	13	4	A	S	0.39
LaCrosse Dredging Co	....	Dredge	Pump	BuS	1	1,000	300	8	16½	21	4	A	S	0.38
Forrest City	Arkansas	Mun. Pwr.	Gen.	DLV	1	1,000	240	8	17½	24	4	A	S	....
350–875 Hp. per Engine														
Grafton	N. Dakota	Mun. Pwr.	Gen.	FM	1	875	300	5	16	20	2	A	S	0.39
Sellers Mfg. Co	Saxapahaw, N. C.	Pwr.	Gen.	Sup	1	810	360	8	14½	18	4	A	S	....
Wahoo	Nebraska	Mun. Pwr.	Gen.	BuS	2	750	257	6	16¼	24½	4	A	S	0.38
Oxford	Mississippi	Pwr.	Gen.	ALC	1	750	225	6	17½	25	4	A	S	0.39
Broken Bow	Nebraska	Mun. Pwr.	Gen.	FM	1	750	257	5	16	20	2	A	S	0.39
St. Genevieve Lime & Quarry Co	Mosher, Mo.	Pwr.	Gen. & Comp.	Sup	1	750	327	8	14½	18	4	A	S	....
					1	375	327	4	14½	18	4	A	S	....
Georgetown	Texas	Mun. Pwr.	Gen.	FM	1	750	257	5	16	20	2	A	S	0.39
Farmville	N. Carolina	Mun. Pwr.	Gen.	ALC	1	730	257	5	17½	25	4	A	S	0.39
					1	445	257	3	17½	25	4	A	S	0.39
Yuba Mfg. Co	Seattle, Wash.	Dredge	Gen.	ALC	1	720	600	8	12½	13	4	A	S	0.49
Eastern Shore Pub. Serv. Co	Tasley, Va.	C. S. Add.	Gen.	ALC	1	715	257	5	17½	25	4	A	S	0.39
Minneapolis	Kansas	Mun. Pwr.	Gen.	FM	1	700	300	4	16	20	2	A	S	0.30
Lewes	Delaware	Mun. Add.	Gen.	FM	1	700	300	4	16	20	2	A	S	0.39
U. S. Engineers	St. Paul, Minn.	Dredge	Gen.	ALC	4	650	550	8	12½	13	4	A	S	0.40
Hutchinson	Minnesota	Mun. Add.	Alt.	ALC	1	625	225	5	17½	25	4	A	S	0.39
Onawa	Iowa	Mun. Pwr.	Gen.	ALC	2	625	225	5	17½	25	4	A	S	0.39
Texas Empire Pipe Line Co	Sheldon, Mo.	Oil	Pump	ALC	1	600	212	5	17½	25	4	A	S	0.41
Florida Pub. Utility Co	Fernandina, Fla.	C. S. Pwr.	Gen.	BuS	1	600	225	4	16½	23	4	A	A	0.42
Lake Mills	Wisconsin	Mun. Add.	Gen.	FM	1	600	400	6	12	15	2	A	S	0.40
Elk Point	S. Dakota	Mun. Pwr.	Gen.	FM	1	575	300	5	14	17	2	A	S	0.42
Columbia Quarry Co	Volmeyer, Ill.	Pwr.	Gen.	Sup	1	560	400	8	12½	15	4	A	S	....
Sternberg Dredging Co	St. Louis, Mo.	Dredge	Gen.	ALC	1	540	600	6	12½	13	4	A	S	0.40
Columbia Quarry Co	Columbia, Ill.	Pwr.	Gen.	Sup	1	525	375	8	12½	15	4	A	S	....
					1	400	375	6	12½	15	4	A	S	....
Thorres & Maes Mfg. Co	Jackson, Mich.	Pwr.	Gen.	FM	1	500	400	5	12	15	2	A	S	0.40
Stanolind Pipe Line Co	Beck, Neb.	Oil	Pump	BuS	1	500	277	4	16½	24½	4	A	S	0.39
Hallettsville	Texas	Mun. Pwr.	Gen.	FM	1	500	400	5	12	15	2	A	S	0.40
Jonesboro	Louisiana	Mun. Pwr.	Gen.	FM	1	500	400	5	12	15	2	A	S	0.40
Texas Empire Pipe Line Co	Various	Oil	Pump	BuS	5	500	225	5	16¼	23	4	A	A	0.42
No. 2 Park Ave. Bldg	New York, N. Y.	Lt. & Pwr.	Gen.	Wor	4	450	327	6	13¼	17½	4	A	S	0.40
Villisca	Iowa	Mun. Pwr.	Gen.	FM	2	450	300	6	14	17	2	A	S	0.38
Keeler Brass Co	Grand Rapids, Mich.	Pwr.	Gen.	BuS	1	450	360	6	13	17	4	A	S	0.39
Farmer City	Illinois	Mun. Add.	Gen.	FM	1	450	300	6	14	17	2	A	S	0.38
Central Rubber Co	Findlay, Ohio	Pwr.	Gen.	FM	1	450	300	6	14	17	2	A	S	0.38
Pevely Dairy Co	St. Louis, Mo.	Pwr. Add.	Comp.	BuS	1	450	225	4	16¼	24½	4	A	S	0.39
Wolfeboro	New Hampshire	Mun. Pwr.	Gen.	FM	1	450	300	6	14	17	2	A	S	0.38
LaCrosse Dredging Co	....	Pwr.	Gen.	BuS	1	450	360	6	13	17	4	A	S	0.39
Southern New England Ice Co	Bridgeport, Conn.	Pwr.	Shaft	Sup	1	420	300	8	12½	15	4	A	S	....
				Sup	1	315	300	6	12½	15	4	A	S	....
N. Y. Telephone Co	New York, N. Y.	Emer. Pwr.	Alt.	ALC	1	415	720	8	9½	10¾	4	A	S	0.40
Buckeye Pipe Line Co	Mt. Cory, Ohio	Oil	Pump	Sup	2	400	380	6	12½	15	4	A	S	....
International Milling Co	Minneapolis, Minn.	Pwr.	Shaft	DLV	1	400	225	4	17	24	4	A	S	....
Walters	Oklahoma	Mun. Pwr.	Gen.	BuS	1	400	225	4	16¼	23	4	A	A	0.42
Humble Pipe Line	Houston, Tex.	Oil	Pump	DLV	1	400	225	4	17	24	4	A	S	....
Hanley Milling Co	Mansfield, Ohio	Pwr.	Gen.	Sup	1	380	360	6	12½	15	4	A	S	....
Gainesville	Texas	W.W.	Pump	C-B	1	375	327	8	11¼	15	4	A	A	....
Ackley	Iowa	Mun. Pwr.	Gen.	FM	1	375	300	5	14	17	2	A	S	0.41
Simonds Saw & Steel Co	Fitchburg, Mass.	Pwr.	Alt.	ALC	1	375	360	5	12½	18	4	A	S	0.39
Cone Automatic Mach. Co	Windsor, Vt.	Pwr.	Gen.	FM	1	375	300	5	14	17	2	A	S	0.38
Connersville	Indiana	W.W.	Pump	C-B	2	363	400	6	11¼	15	4	A	....	....
Indiana Pipe Line Co	Griffith, Ind.	Oil	Pump	ALC	2	360	340	5	12½	18	4	A	S	0.39
Continental Pipe Line Co	Edmond, Okla.	Oil	Pump	Sup	1	350	600	8	9	12	4	A	S	....
Superior Oil Producing Co	Bruni, Texas	Pwr.	Drills	Sup	2	350	600	8	9	12	4	A	S	....
Standish Pipe Line Co	Edgerton, Kan.	Oil	Pump	Sup	2	350	600	8	9	12	4	A	S	....
Loffland Bros	Oklahoma City, Okla.	Pwr.	Drills	Sup	4	350	600	8	9	12	4	A	S	....
					2	260	600	6	9	12	4	A	S	....

ABBREVIATIONS—ALC—American Locomotive Co., BuS—Busch-Sulzer, C-B—Cooper-Bessemer, DLV—DeLaVergne, FM—Fairbanks Morse, HOR—Hooven, Owens, Rentschler, Nor—Nordberg, R-J—Rathbun-Jones, Sup—National Supply Co. (Superior), WIW—Washington Iron Works, Add.—Addition, Alt.—alternator, Comp.—compressor, CS—central station, Emer.—emergency, Gen.—generator, Lt.—light, Mun.—municipal, Pwr.—power, Ref.—refrigeration, W.W.—water works.

Under fuel injection—A is air, S is solid. Under starting method—A is air, E is electric, G is gasoline, AE is automatic electric.

Owner	Location	Service	Equipt. Driven	Engine Builder	No. Units	Horse-power Each	Speed R.P.M.	No. Cyl.	Cyl. Bore	Cyl. Stroke	Cycle	Starting Method	Fuel Injection	Fuel Consump. lb. per hp. hr.
Continental Oil Co.	Nacona, Texas	Pwr.	Gen.	Sup	1	350	600	8	9	12	4	A	S	....
Korn Leather Co.	Peabody, Mass.	Pwr.	Gen.	Bro	2	350	400	5	11	17½	4	A	S	0.38
Texas Pipe Line Co.	Manuel, Texas	Oil	Pump	Sup	2	350	600	8	9	12	4	A	S	....
Texas Empire Pipe Line Co.	Texas	Oil	Pump	ALC	1	340	225	3	17	24	2	A	A	0.41
National Supply Co.	Houston, Texas	Pwr.	Gen.	Sup	1	330	400	5	11½	14	4	A	S	....
					1	300	514	8	9	12	4	A	S	....
New York University	New York, N. Y.	Pwr. & Lt.	Alt.	ALC	1	310	720	6	9½	10½	4	A	S	0.40
					2	225	360	3	12½	18	4	A	S	0.40
U. S. Gypsum Co.	N. Kansas City, Mo.	Pwr.	Alt.	ALC	1	310	720	6	9½	10½	4	A	S	0.40
Curtis Electric Co.	New York, N. Y.	Lt. & Pwr.	Gen.	Nor	2	300	400	6	10½	15	4	A	S	....
Buckeye Pipe Line Co.	New York, N. Y.	Oil	Pump	C-B	1	300	435	6	10½	13½	4	A	A	....
White Cloud	Michigan	Mun. Pwr.	Gen.	FM	1	300	300	4	14	17	2	A	S	0.38
Girard	Pennsylvania	Mun. Pwr.	Gen.	FM	2	300	300	4	14	17	2	A	S	0.38
Humble Pipe Line Co.	Hearne Texas	Pwr.	Alt.	BuS	2	300	400	4	13	17	4	A	S	0.39
Elroy	Wisconsin	Mun. Pwr.	Gen.	FM	1	300	300	4	14	17	2	A	S	0.38
Standish Pipe Line Co.	Oklahoma City, Okla.	Oil	Pump	Sup	1	300	514	8	9	12	4	A	S	....
Hominy	Oklahoma	Mun. Pwr.	Gen.	Nor	3	300	400	6	10½	15	4	A	S	....
Sylvania	Georgia	Mun. Pwr.	Gen.	FM	1	300	300	4	14	17	2	A	S	0.38
Herndon	Kansas	Mun. Pwr.	Gen.	FM	1	300	300	4	14	17	2	A	S	0.40
Am. Sanitary Mfg. Co.	Abdington, Ill.	Pwr.	Gen.	Buc	1	300	400	8	9½	14	4	A	S	0.40
St. Anne Brick & Tile Co.	St. Anne, Ill.	Pwr.	Gen.	Buc	1	300	400	8	9½	14	4	A	S	0.40
Cascade Laundry	Brooklyn, N. Y.	Pwr.	Gen.	CP	1	300	.....	6	...	...	4	A	S	....
				Bud	1	52	1,500	6	4	5½	4	E	S	....
Texas Pipe Line Co.	South Bend, Texas	Oil	Pump	Sup	1	300	514	8	9	12	4	A	S	....
Sabina	Ohio	Mun. Pwr.	Gen.	FM	1	300	300	4	14	17	2	A	S	0.41
150–275 Hp. per Engine														
Friday Harbor Lt. & Pwr. Co.	Friday Harbor, Wash.	Mun. Pwr.	Alt.	WIW	1	275	300	6	11½	15	4	A	S	0.42
Waimea Garage & Electric Co.	Hawaii	Pwr.	Alt.	WIW	1	275	300	6	11½	15	4	A	S	0.42
Madison Packing Co.	Madison, Ill.	Pwr.	Gen.	Buc	1	262½	400	7	9½	14	4	A	S	0.40
Nelson Creek Coal Co.	Nelson, Ky.	Pwr.	Gen.	Buc	1	262½	400	7	9½	14	4	A	S	0.40
Central Mills, Inc.	Dunbridge, Ohio	Alfalfa	Mill	Buc	1	262½	400	7	9½	14	4	A	S	0.40
Hope Brick Works	Hope, Ark.	Pwr.	Mill	Buc	1	262½	400	7	9½	14	4	A	S	0.40
American Liberty Pipe Line Co.	Crockett, Texas	Oil	Pump	Sup	2	260	600	6	9	12	4	A	S	....
American Liberty Pipe Line Co.	Dodge, Texas	Oil	Pump	Sup	2	260	600	6	9	12	4	A	S	....
Texas Pipe Line Co.	San Augustine, Texas	Oil	Pump	Sup	1	260	600	6	9	12	4	A	S	....
Klondike Fluorspar Corp.	Smithland, Ky.	Pwr.	Pump	Sup	1	260	600	6	9	12	4	A	S	....
American Liberty Pipe Line Co.	Rusk, Texas	Oil	Pump	Sup	2	260	600	6	9	12	4	A	S	....
Montrose Clay Products Co.	Montrose, N. Y.	Pwr.	Shaft	Sup	1	260	600	6	9	12	4	A	S	....
W. J. Kunkel	Readville, Mass.	Pwr.	Gen. & Comp.	DLV	1	260	277	4	14½	18	4	A	S	....
Empire Trust Bldg.	New York, N. Y.	With steam	Gen.	I-R	2	250	514	5	10	12	4	A	S	....
Gulfport Ice Co.	Gulfport, Miss.	Pwr.	Gen.	Sup	1	250	360	4	12½	15	4	A	S	....
Wright & Sons	Elizabeth City, N. C.	Ref.	Comp.	WIW	1	240	277	4	13	16	4	A	S	0.42
Owensboro Milling Co.	Owensboro, Ky.	Flour	Mill	Buc	1	225	400	6	9½	14	4	A	S	0.40
Holgate Bros.	Kane, Pa.	Pwr.	Gen.	Buc	1	225	400	6	9½	14	4	A	S	0.40
Holton	Kansas	Mun. Pwr.	Gen.	Ful	1	225	300	3	13½	18	4	A	S	0.40
Driggs Dairy Farms, Inc.	Toledo, Ohio	Pwr.	Gen.	Buc	1	225	400	6	9½	14	4	A	S	0.40
Universal Insulation Co.	Libby, Mont.	Pwr.	Gen.	Sup	1	215	600	5	9	12	4	A	S	....
Eureka Stone Co.	Chalfort, Pa.	Pwr.	Gen	Sup	1	215	600	5	9	12	4	A	S	....
J. A. Miller Tile Co.	Bascom, Ohio	Pwr.	Shaft	Sup	1	210	600	6	8½	11	4	A	S	....
Continental Oil Co.	Ponca City, Okla.	Oil	Pump	DLV	1	200	1,200	6	7	8	4	A	S	....
Southern Flour Mills	Albemarle, N. C.	Flour	Mill	Buc	1	187½	400	5	9½	14	4	A	S	0.40
H. A. Holdridge Co.	Lima, Ohio	Flour	Mill	Buc	1	187½	400	5	9½	14	4	A	S	0.40
Trimble Nurseryland Furniture Co.	Rochester, N. Y.	Pwr.	Gen.	Buc	1	187½	400	5	9½	14	4	A	S	0.40
The Moore Bros. Co.	Elizabeth, N. J.	Pwr. & Air	Gen. Comp.	Wor	1	180	600	6	8	10½	4	A	S	....
				Wor	1	90	600	3	8	10½	4	A	S	....
Red River Refining Co.	Burnham, Ill.	Pwr.	Gen.	Sup	2	175	600	4	9	12	4	A	S	....
Connersville Ice Co.	Connersville, Ind.	Ref. & Pwr.	Comp & Gen.	Sup	1	165	300	4	11½	14	4	A	S	....
Brookside Ice Co.	E. Hartford, Conn.	Pwr.	Gen.	Cum	1	165	720	4	6	7	9	A	S	....
Regal Laundry	Baltimore, Md.	Pwr..	Gen.	St	1	165	1,200	4	4½	5½*	2	E	S	....
Socorro Mines	California	Mine	Gen.	Cat	1	160	850	8	5½	8	4	G	S	0.44
					2	125	850	6	5½	8	4	G	S	0.43
Simrall Corp	Michigan	Oil	Pump	Cat	7	160	850	8	5½	8	4	G	S	0.44
Blue Line Hosiery Co.	Denver, Pa.	Pwr.	Gen.	FM	1	150	300	2	14	17	2	A	S	0.38
Federal Cartridge Co.	Anoka, Minn.	Pwr.	Gen.	FM	2	150	300	2	14	17	2	A	S	0.38
H. C. Knoke & Co.	Chicago, Ill.	Pwr.	Gen.	Buc	1	150	400	4	9½	14	4	A	S	0.40
Cook Bros. Gin Co.	Arp, Texas	Pwr.	Shaft	TIW	1	150	250	2	13	18	2	A	S	0.40
Belhaven	N. Carolina	Mun. Pwr.	Gen.	FM	2	150	300	2	14	17	2	A	S	0.38
Burdette Oxygen Co.	Ft. Worth, Texas	Air & Pwr.	Comp.	FM	1	150	300	2	14	17	2	A	S	0.38
City Flouring Mills	Muncy, Pa.	Flour	Mill	Buc	1	150	400	4	9½	14	4	A	S	0.40
Middleton Gin Co.	Madisonville, Texas	Pwr.	Shaft	TIW	1	150	250	2	13	18	2	A	S	0.40
Carlisle & Doughty, Inc.	Conshohocken, Pa.	Pwr.	Gen.	Buc	1	150	400	4	9½	14	4	A	S	0.40
Bangor Fidelity Slate Co.	Bangor, Pa.	Pwr.	Gen.	Buc	1	150	400	4	9½	14	4	A	S	0.40
Smith Milling Co.	Milwaukee, Wis.	Pwr.	Gen.	TIW	1	150	250	2	13	18	2	A	S	0.40
Volco Wire Co.	Kenilworth, N. J.	Pwr.	Gen.	Buc	1	150	400	4	9½	14	4	A	S	0.40
Werner Foundry, Inc.	Lansdale, Pa.	Pwr. & Air	Comp. & Gen.	Buc	1	150	400	4	9½	14	4	A	S	0.40
Bridgeton Sand Co.	Bridgeton, N. J.	Dredge	Pump	Cum	1	150	800	6	6½	9	4	A	S	....
Gillespie Ice & Fuel Co.	Gillespie, Ill.	Pwr. & Ref.	Comp. & Gen.	Buc	1	150	360	4	9½	14	4	A	S	0.40
N. Carolina Talc Co.	Carthage, N. C.	Talc Mill	Gen.	Std	1	150	360	6	8½	12	4	A	S	0.45
					1	125	360	4	8	10	4	A	S	0.45
100–140 Hp. per Engine														
Michigan Cleaners	Chicago, Ill.	Pwr.	Gen.	Bud	1	140	1,200	6	5½	7	4	E	S	....
Belvidere Water Works	Belvidere, Ill.	Pwr.	Gen.	Bud	1	140	1,200	6	5½	7	4	E	S	....
United Milk & Ice Cream Co.	Chicago Heights, Ill.	Pwr.	Gen.	Bud	1	140	1,200	6	5½	7	4	E	S	....
Champion Pneumatic Co.	Chicago, Ill.	Pwr.	Gen.	Bud	1	140	1,200	6	5½	7	4	E	S	....
Dooley Elect. Co.	New York, N. Y.	Pwr.	Gen.	Sup	2	130	600	3	9	12	4	A	S	....
Murray Drilling Co.	Kansas	Oil Well	Drill	Cat	1	125	850	6	5½	8	4	G	S	0.43
Utah Sand & Gravel Co.	Nevada	Ballast	Crusher	Cat	2	125	850	6	5½	8	4	G	S	0.43
Bay City Co.	Texas	Pwr.	Shaft	Cat	1	125	850	6	5½	8	4	G	S	0.43
Continental Oil Co.	Ponca City, Okla.	Oil	Pump	DLV	1	120	600	3	9	11	4	A	S	....
Municipal Pumping Station	North Easton, Mass.	W. W.	Pump	Her	1	120	2,000	6	4½	5½	4	AE	S	....
City Ice & Fuel Co.	Janesville, Wis.	Ref.	Comp.	FM	1	120	360	2	12	15	2	A	S	0.40
Illinois Pipe Line Co.	Chatham, Wyo.	Oil	Pump	Sup	1	115	514	3	9	12	4	A	S	....
Siler City Mills	Siler City, N. C.	Flour Add.	Mill	Buc	1	112½	400	3	9½	14	4	A	S	0.40
Calnen Ice Co.	Richmond, Mo.	Ref.	Comp.	Buc	1	112½	360	3	9½	14	4	A	S	0.40
R. L. Harrison & Son	Bagdad, Ky.	Flour	Mill	Buc	1	112½	400	3	9½	14	4	A	S	0.40
Blue Ridge Storage Co.	Staunton, Va.	Pwr. & Ref.	Comp. & Gen.	Buc	1	112½	400	3	9½	14	4	A	S	0.40
Zeigler Bros.	Gettysburg, Pa.	Flour	Mill	Buc	1	112½	400	3	9½	14	4	A	S	0.40
Tobacco River Pwr. Co.	Eureka, Mont.	Lt. & Pwr.	Gen.	FM	1	110	360	2	12	15	2	A	S	0.42
Rubber Refining Co.	Brooklyn, N. Y.	Pwr.	Mill	Cum	1	110	1,500	6	4½	6	4	A	..	....
Tallulah Ice & Cold Storage Co.	Tallulah, La.	Ref.	Comp.	C-B	1	110	327	2H	10½	15	2	A	S	....
Harvey D. Able	Columbia, Pa.	Pwr. & Lt.	Gen.	Sup	1	105	514	4	9	12	4	A	S	....
Sternberg Co.	Florida	Dredge	Gen.	Cat	1	100	850	6	5½	8	4	G	S	0.43
U. of Texas Observatory	Mt. Locke, Texas	Lt. & Pwr.	Gen.	Win	1	100	600	6	6½	8½	4	E	S	0.40
					1	50	600	3	6½	8½	4	E	S	0.41
Marvel Maid Garment Co.	Lima, Ohio	Pwr.	Gen.	Buc	1	100	514	5	7½	10½	4	A	S	0.40
Schmidt Provisions Co.	Toledo, Ohio	Pwr.	Gen.	Buc	2	100	514	5	7½	10½	4	A	S	0.40
Patent Novelty Co.	Fulton, Ill.	Pwr.	Gen.	Buc	1	100	514	5	7½	10½	4	A	S	0.40
Pennsburg Silk Co.	Pennsburg, Pa.	Pwr.	Gen.	Buc	1	100	514	5	7½	10½	4	A	S	0.40
Mueller Furniture Co.	Grand Rapids, Mich.	Pwr.	Gen.	Buc	1	100	514	5	7½	10½	4	A	S	0.40
Grand Rapids Parlor Frame Co.	Grand Rapids, Mich.	Pwr.	Gen.	Buc	1	100	514	5	7½	10½	4	A	S	0.40
Crystal Ice Co.	Wildwood, N. J.	Ref.	Comp.	Sup	1	100	600	5	7	9	4	A	S	....
Murray Furniture Co.	Grand Rapids, Mich.	Pwr.	Gen.	Buc	1	100	514	5	7½	10½	4	A	S	0.40

Owner	Location	Equipt. Driven	Engine Builder	No. Units	Hp. Each	R.p.m.	No. Cyl.	Cyl. Bore	Cyl.Stroke	Starting Method
Cvgtn. Iron & Fdry Co., Covington, Va..		Gen.	Std.	2	90	600	6	6	8	A
				1	60	600	4	6	8	A
E. C. Lynch, Locust Valley, N. Y.		Gen.	Rus.	1	88	1,000	5	5¼	8	A
H. E. Dye, Furbotville, Pa.		Mill	Cum.	1	85	1,200	6	4¼	6	A
G. W. Lillich, Abbottstown, Pa.		Gen.	Cum.	1	85	1,200	6	4¼	6	A
Paul Lehman, York Springs, Pa.		Gen.	Cum.	1	85	1,200	6	4¼	6	A
Hartford Retreat, Hartford, Conn.		Gen.	Cum.	1	85	1,200	6	4¼	6	A
Allerton Hotel, New York, N. Y.		Gen.	Bud.	2	85	900	6	5½	7	AE
Cromwell Water Co., Cromwell, Conn.		Pump	Cum.	1	85	1,200	6	4¼	6	A
Broadway Cent. Hotel, New York, N. Y.		Gen.	Bud.	3	85	900	6	5½	7	AE
Valley Forge M. A., Valley Forge, Pa.		Gen.	Cum.	2	85	1,200	6	4¼	6	A
100 W. 55th St. (Apt.) New York, N. Y.		Gen.	Bud.	2	85	900	6	5½	7	AE
Post Brick Co., Glenhead, L. I., N. Y.		Comp.	Cum.	1	85	1,200	6	4¼	6	A
Keystone Lamp Mfg. Co., Slatington, Pa.		Gen.	Sup.	1	84	1,200	8	4½	5¼	E
George E. Farley, Midland, Texas.		Shaft	Sup.	1	84	1,400	8	4½	5¼	E
				1	62	1,200	6	4½	5¼	E
National Supply Co., Springfield, Ohio..		Gen.	Sup.	1	84	1,200	8	4½	5¼	E
H. Leonard, Inc., Rosswell, N. Mex.		Shaft	Sup.	1	84	1,400	8	4½	5¼	E
Paton Bros., Artesia, N. Mex.		Shaft	Sup.	1	84	1,400	8	4½	5¼	E
Penn. R. R. Co., Altoona, Pa.		Gen.	Sup.	2	84	1,200	8	4½	5¼	E
Oxford Co., Oxford, Pa.		Gen.	Sup.	1	84	1,200	8	4½	5¼	E
Leiman-Weidman Box Co., Tampa, Fla.		Gen.	Sup.	1	84	1,200	8	4½	5¼	E
Seville Hotel, New York, N. Y.		Gen.	Bud.	4	82	900	6	5½	7	AE
Avalon Dairy, Middleton, Ohio.		Gen.	Buc.	1	80	514	4	7½	10¼	A
Gaffney Ice Co., Gaffney, N. C.		Gen.	Buc.	1	80	514	4	7½	10¼	A
Hatteras Devel. Co., Belhaven, N. C.		Gen.	Buc.	1	80	514	4	7½	10¼	A
Hickory Mills, Inc., Hickory, N. C.		Mill.	Buc.	1	80	514	4	7½	10¼	A
New Paris Elev. Co., New Paris, O.		Gr.El.	Sup.	1	80	600	4	7	9	A
Banner Roller Mills, Lincolnton, N. C.		Mill.	Buc.	1	80	514	4	7½	10¼	A
Furn. City Platg. Co., Grnd. Rap., Mich.		Gen.	Buc.	1	80	514	4	7½	10¼	A
Morse Co., Maine.		Shaft	Cat.	1	80	850	4	5½	8	G
Geo. Auchter Co., Florida.		Comp.	Cat.	2	80	850	4	5½	8	G
Rau & Griffin, New York.		Shaft	Cat.	1	80	850	4	5½	8	G
McIver Co., Texas.		Shaft	Cat.	1	80	850	4	5½	8	G
Mt. Ver. Die Cast. Co., Mt. Vernon, N. Y.		Gen.	Kr‡	2	78	514	3	5 15/16	10 7/16	A
St. Catherine Coll., Minneapolis.		Gen.	St.‡	1	75	1,200	4	3½	4½*	E
San Jose Hospital, Los Angeles, Cal.		Gen.	St.‡	1	75	1,200	4	3½	4½*	E
Amer. Ice. Co., N. Sacramento, Cal.		Alt.†	St.‡	2	75	1,200	4	3½	4½*	E
Swayze Folding Box Co., Canton, Pa.		Gen.	Buc.	3	75	400	2	9½	14	A
Waterloo Coal Co., Oak Hill, Ohio.		Gen.	FM‡	1	75	300	1	14	17	A
Flemhg. Ice Co., Flemingsburg, Ky.		Comp.	FM‡	1	75	300	1	14	17	A
Bordens Farm Products, New York, N.Y.		Gen.	Cum.	3	75	1,100	6	4¼	6	A
Sussex Milk & Cream Co., Sussex, N. Y.		Comp.	Cum.	1	70	900	6	4¼	6	A
Lyman Gun Sight Cor., Mid'field, Conn.		Gen.	Cum.	1	70	720	6	4¼	6	A
Kougarok Placers, Inc., Alaska.		Pump	WIW	2	68	450	3	8½	10	A
James Donohue, Mountainview, N. J.		Gen.	Rus.	1	66	265	1	12½	22	A
Gibson Ice Co., Muncie, Ind.		Gen.	Sup.	1	65	500	4	7	9	A
Campbell Mach. Co., San Diego, Calif..		Gen.	Hill	1	65	720	6	5	7	E
			Sup.	1	42	1,200	4	4½	5¼	E
			Hill	1	43	720	4	5	7	E
N. W. Jr. High School, Reading, Pa.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
G. Cella, Inc., New York, N. Y.		Gen.	Sup.	2	62	1,200	6	4½	5¼	E
Russell Erie Shipyd., Brooklyn, N. Y.		Pump	Sup.	4	62	1,335	6	4½	5¼	E
		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Bonton Cleaners, Miami, Fla.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
Crown Williamette Paper, Frisco.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
Wheeler Shipyard, Brooklyn, N. Y.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
American Laundry Co., Trenton, N. J.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
Frank Silva, Point Loma, Calif.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
Manuel Medina, San Diego, Calif.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
Main Central Hotel, Asbury Park, N.J..		Gen.	Sup.	2	62	1,200	6	4½	5¼	E
Wm. R. Thropp & Sons, Trenton, N. J.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
General Cable Co., Perth Amboy, N. J.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
Arundel Corp., Stuart, Fla.		Gen.	Sup.	1	62	1,200	6	4½	5¼	E
J. McWilliams, Staten Island, N. Y.		Pump	Sup.	2	62	1,200	6	4½	5¼	E
Hunterdon Coop. Ser., Flemington, N.J.		Shaft	Sup.	1	62	1,200	6	4½	5¼	E
Cotuit, Mass.		Pump	Wor.	1	60	600	2	8	10½	A
Marietta Mfg. Co., Pt. Pleasant, W. Va..		Pump	FM	8	60	1,200	6	4½	6	E
George E. Judd, Ft. Myers, Fla.		Gen.	Sup.	2	60	600	3	7	9	A
Glasco Milling Co., Glasco, Kan.		Shaft	Wor.‡	1	60	375	2	10½	10¼	A
Stockton, Illinois.		Pump	FM	1	60	1,200	6	4¼	6	E
Blackstone Ice Co., Blackstone, Va.		Comp.	Buc.	1	60	514	3	7½	10¼	A
Sanford Ice & Coal Co., Sanford, N. C.		Comp.	Buc.	1	60	514	3	7½	10¼	A
Wareham, Mass.		Gen.	FM‡	1	60	360	1	12	15	A
Oakdale Ice Co., Oakdale, La.		Gen.	Sup.	2	60	600	3	7	9	A
Lake & Reagan, Colfax, Ind.		Gen.	FM‡	1	60	360	1	12	15	A
Gt. Barr. Ice Co., Gt. Barrington, Mass.		Comp.	FM‡	1	60	360	1	12	15	A
1 Christopher St., New York, N. Y.		Gen.	Bud.	2	60	720	6	5¼	7	E
J. H. Brown, Texas.		Pump	Cat.	1	60	850	3	5½	8	G
Willow Brook Dairy, Mt. Vernon, N. Y.		Comp.	Cum.	2	60	800	6	4¼	6	A
Foxboro, Mass.		Pump	Cat.	1	60	850	4	5½	8	G
U.S. Hmmd. Piston Ring Co., Str'lg, N.J.		Gen.	Std.	1	60	600	4	6	8	A
W. F. Smith, Utah.		Gen.	Cat.	2	60	850	3	5½	8	G
Seger Seed Co., Jackson, Minn.		Shaft	TIW‡	1	59	275	1	12	15	A
Penn Rock Oil Synd., Tionesata, Pa.		Comp.	TIW‡	1	58	270	1	12	15	A
Pillar of Fire, Zaraphath, N. J.		Gen.	Rus.	1	57	275	1	11¾	21	A
Club Edgewood, E. Greenbush, N. Y.		Gen.	Rus.	1	57	275	1	11¾	21	A
				1	22	360	1	7¼	15¾	A
James Kalddemas, Southampton, N. Y..		Gen.	Cum.	1	55	1,200	4	4¼	6	A
Lincoln Stor. Warehse., New York, N. Y.		Gen.	Bud.	1	52	1,200	6	4½	5¼	E
Ye Eat Shoppe, New York, N. Y.		Gen.	Bud.	2	52	1,200	6	4½	5¼	AE
Wyman Restaurant, Arlington, Mass.		Gen.	Bro.‡	1	50	480	2	6 15/16	9¼	E

30–50 Hp. per Engine

The Tavern, Troy, N. Y.		Gen.	Rus.	1	47	290	1	10¾	19½	A
E. E. Childs, Long Island, N. Y.		Gen.	Rus.	1	47	290	1	10¾	19½	A
Sisco Dairy, Clifton, N. J.		Gen.	Rus.	2	47	290	1	10¾	19½	A
J. Clemens, Mainland, Pa.		Gen.	Rus.	1	47	290	1	10¾	19½	A
Tennis Gardens Apt., Forest Hills, N. Y.		Gen.	Cum.	3	46	720	6	4¼	6	A
Rud. Wind, Babylon, L. I., N. Y.		Gen.	Sch.	1	45	900	3	5¼	7 3/32	E
				1	20	900	2	4 9/16	6¾	E
Neilsen Ice Cream Co., Pt. Chester, N.Y.		Comp.	Sch.	1	45	900	3	5¼	7 3/32	A
C. V. Maddux, Colorado.		Pump	Cat.	3	44	1,400	4	4¼	5¼	G
Newcomb Hotel, Illinois.		Gen.	Cat.	2	44	1,400	4	4¼	5¼	G
Paul Mulkey, Alabama.		Shaft	Cat.	1	44	1,400	4	4¼	5¼	G
Park Cleaners, Springfield, Mass.		Shaft	Hill.	1	43	720	4	5	7	E
S. W. Jr. High School, Reading, Pa.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
Columbia Packers Assn., Seattle.		Pump	Sup.	1	42	1,200	4	4½	5¼	E
Loffland Bros., Price, Utah.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
Roch'ter Tel. Corp., Rochester, N. Y.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
N. Y. C. Fire Dept., New York, N. Y.		Gen.	Sup.	2	42	1,200	4	4½	5¼	E
U. S. Engineers, Pittsburgh, Pa.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
J. S. Morie, Vineland, N. J.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
Phila. Dry Cleaners, Pottstown, Pa.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
W. J. Smith Co., Catasauqua, Pa.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
Pioneer Ice Cream Corp., Peekskill, N.Y.		Comp.	Cum	1	42	800	4	4¼	6	E
U. S. Dept. Int., Albuquerque, N. Mex.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
U. S. Treas. Dept., New Haven, Conn.		Gen.	Sup.	2	42	1,200	4	4½	5¼	E
Keystone Sd. & Sup. Co., Pittsburgh, Pa.		Gen.	Sup.	1	42	1,200	4	4½	5¼	E
H. Schindler & Co., Canton, Mass.		Gen.†	Her.	2	40	1,200	6	3¾	4¼	AE
Imperial Laundry Co., Newark, N. J.		Gen.	FM	1	40	1,200	6	4¼	4	E
Point O'Woods Assn., Long Island, N. Y.		Gen.	Lis.	1	38	1,000	4	4½	5¼	H
John Boyle Co., Bradford, Pa.		Pump	TIW‡	1	38	250	1	10¾	14	A
Kansas Packing Co., New York, N. Y.		Comp.	Lis.	1	38	1,000	4	4½	5¼	H
		Pump	Lis.	1	18	1,000	2	4½	5¼	H
Waterville Mfg. Co., Waterbury, Conn.		Shaft	Lis.	1	38	1,000	4	4½	5¼	H
Decamp Bus Lines, Livingston, N. J.		Gen.	Rus.	1	34	310	1	9¼	17½	A
J. Dilliplane, Yardley, Pa.		Comp.	Rus.	1	34	310	1	9¼	17½	A
M. H. Laipson Crmry, Worcester, Mass.		Comp.	Cat.	1	33	1,400	4	4¼	5¼	G
Stein Ice Co., Fredericksburg, Tex.		Comp.	FM	1	30	1,200	3	4¼	6	E
Weyerhauser Co., Long View, Wash.		Shaft	FM	1	30	1,200	3	4¼	6	E

Under 30 Hp. per Engine

Rutt's Hut, Delawanna, N. J.		Gen.	Rus.	1	28	320	1	8¼	16¼	A
F. E. Schumacher, Hartville, Ohio.		Shaft	Lis.	1	27	1,000	3	4½	5¼	H
Henry's Conf. St., Glen Cove, L. I. N. Y.		Gen.	Sch.	1	27	900	2	5¼	7 3/32	A
Roth Packing Co., Union City, N. J.		Gen.	Lis.	1	27	1,000	3	4½	5¼	H
T. J. Sourbier, Miami, Fla.		Gen.	Lis.	1	27	1,000	3	4½	5¼	H
C. E. Parks, Miami, Fla.		Gen.	Lis.	1	27	1,000	3	4½	5¼	H
Costa Bros., Yonkers, N. Y.		Gen.	Lis.	1	27	1,000	3	4½	5¼	H
OK Tire Shop, New Brunswick, N. J.		Gen.	Hill	1	22	720	2	5	7	E
Imperial Restrt., New Brunswick, N. J.		Gen.	Hill	1	22	720	2	5	7	E
Cosmopolitan Restrt., Asbury Park, N.J.		Gen.	Rus.	1	22	360	1	7¼	15¼	A
Ryan Poultry Farms, Stoughton, Mass.		Gen.	Rus.	1	22	360	1	7¼	15¼	A
Lammont du Pont, Wilmington, Del.		Gen.	Sup.	2	21	1,200	2	4½	5¼	E
Follmer Trucking Co., Milton, Pa.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Jourden Diesel Schools, Phila., Pa.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Kirby & Kirby, Trenton, N. J.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Spadara Const. Co., Moore Haven, Fla.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Mills Novelty Co., Chicago, Ill.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
J. H. Rinehart, Fort Lee, N. J.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Rochester Baird, Lafayette, Ind.		Gen.	Sup.	2	21	1,200	2	4½	5¼	E
R. P. Scripps, Miramar, Calif.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Elia Clemson, Dorothy, N. J.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Columbia Quarry Co., Krause, Ill.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Kent's Rest. & Bakery, Atl. City, N. J.		Gen.	Sup.	1	21	1,200	2	4½	5¼	E
Internat. Refining, Sunburst, Mont.		Pump	Sup.	1	21	1,200	2	4½	5¼	E
Coggswell Spring W. W., Henniker, N.H.		Pump	FM	1	20	1,200	2	4¼	6	H
Torrington Dairy, Torrington, Conn.		Gen.	Bud.	1	18	1,200	4	3¾	4¼	E
H. H. Brown, Monsey, N. Y.		Gen.	Lis.	1	18	1,000	2	4½	5¼	H
Metrop. Ramp Garage, Hartford, Conn.		Gen.	Lis.	1	18	1,000	2	4½	5¼	H
Kavanaugh's Cabin, Delawanna, N. J.		Gen.	Lis.	1	18	1,000	2	4½	5¼	H
Miss Harris School, Miami, Fla.		Gen.	Lis.	1	18	1,060	2	4½	5¼	H
E. M. Maxham, Worcester, Vt.		Shaft	Lis.	1	16	1,200	2	4½	5¼	H
		Gen.	Rus.	1	7½	500	1	5	9¼	H
Triboro Gas Sta., New York, N. Y.		Gen.	Lis.	1	16	1,200	2	4½	4¼	H
Hercules Gas Sta., Brooklyn, N. Y.		Gen.	Lis.	1	16	1,200	2	4½	4¼	H
A. Johns, Ramona, Calif.		Pump	Lis.	1	16	1,200	2	4½	4¼	H
Lee Shipbldg. Co., Cape Cod, Mass.		Gen.	Lis.	1	16	1,200	2	4½	4¼	H
Gilmartin Dairy, Long Island, N. Y.		Gen.	Lis.	1	16	1,200	2	4½	4¼	H
A. C. Ferdon, Upper Montclair, N. J.		Gen.	Lis.	1	16	1,200	2	4½	4¼	H
Franklin Grill, Long Island, N. Y.		Gen.	Rus.	1	13	360	1	7	13½	H
C. M. Fauci, Medford, Mass.		Gen.	Bro.‡	1	12	750	1	4 15/16	6½	A
Borgeson Bros., Waterbury, Conn.		Gen.	Lis.	1	10	600	2	4½	5¼	H
Wm. Beach, Georgetown, S. C.		Gen.	Lis.	1	10	600	2	4½	5¼	H
H. S. Shonnard, Georgetown, S. C.		Gen.	Lis.	1	10	600	2	4½	5¼	H
Lectro Engrg. Co., Jacksonville, Fla.		Gen.	Lis.	1	10	600	2	4½	5¼	H
				1	5	600	1	4½	5¼	H
Majestic Market, Miami, Fla.		Gen.	Lis.	1	10	600	2	4½	5¼	H
Knapp Dairy, Jamaica Plains, Mass.		Gen.	Lis.	1	10	600	2	4½	5¼	H
Toner Drug Co., Nantucket Is., Mass.		Gen.	Lis.	1	8	1,200	1	4½	4¼	H
John Sellars, Lexington, Mass.		Comp.	Lis.	1	8	1,200	1	4½	4¼	H
H. A. Miller, Chester, Mass.		Gen.	Lis.	2	8	1,200	1	4½	4¼	H
Moriarty Bros., Manchester, Conn.		Gen.	Lis.	1	8	1,200	1	4½	4¼	H
Harris Hdwe. Co., Washington, D. C.		Gen.	Lis.	1	8	1,200	1	4½	4¼	H
Stubby's Svce. Stn., Huntington, N. Y.		Gen.	Sch.	1	8	900	1	4	6 19/32	H
John Constantine, Lehighton, Pa.		Gen.	Lis.	2	8	1,200	1	4½	4¼	H
Metrop. Ice Co., Somerville, Mass.		Comp.	Rus.	1	7½	500	1	5	9¼	H
Geo. Drexel, White Oak, Ga.		Gen.	Lis.	1	7	1,000	1	4¼	4¼	H
G. A. Ellis, Cornersville, S. C.		Gen.	Lis.	1	5	600	1	4½	5¼	E
H. G. Strachan, Savannah, Ga.		Pump	Lis.	1	5	600	1	4½	5¼	H
Eastn. Lobster Co., Long Island, N. Y.		Pump	Lis.	1	5	600	1	4½	5¼	H
Flinn Plantation, Midway, Ga.		Gen.	Lis.	1	5	600	1	4½	5¼	H

ABBREVIATIONS—ALC—American Locomotive Co., Buc—Buckeye, Bud—Buda, BuS—Busch Sulzer, Bro—Bromfield-Deutz, Cat—Caterpillar, C-B—Cooper-Bessemer, CP—Chicago Pneumatic, Cum—Cummins, DLV—DeLaVergne, FM—Fairbanks Morse, Ful—Fulton, Her—Hercules, Hill—Hill, I-R—Ingersoll-Rand, Kr—Krupp-Modaag, Lis—Lister, Nor—Nordberg, Rus—Ruston, Sch—Schlueter, Std—Standard, Sup—National Supply Co. (Superior), St—Sterling, TIW—Titusville Iron Works, Win—Winton, WIW—Washington Iron Works, Wor—Worthington.

Under starting method A is air, E is electric, G is gasoline, H is hand, AE is automatic electric.

† double-end units, * opposed-piston units

‡ 2-cycle engines

SUMMARY AND DISCUSSION

CONTINUING increases in stationary-plant installations of diesel engines are indicated by this list of 490 engines in 365 plants, as compared with 307 engines in 190 plants last June. Assuming that 400,000 hp. of 1936 production of 2,000,000 hp. was in stationary-plant engines this listing includes 31% of the total. Assuming that 200,000 hp. of the 400,000 were in engines of 150 hp. and above, this listing represents 53.8% of the total. Actually, coverage is somewhat higher, because no deductions have been made for exported engines. Units above 150 hp. include 211 engines totalling 107,762 hp., smaller ones 279 engines totalling 15,720 hp. As usual, the table is most complete in large-engine installations, where the greatest plant-design variations occur, growing progressively less complete in smaller sizes.

Several interesting trends are apparent. Increasing rotative speeds have brought more multi-cylinder units with smaller bore and stroke. Apparently, no double-acting engines have been sold recently. There is a marked continuance of the trend toward solid-injection and vertical units, although this table marks the first listings of opposed-piston horizontal types. Most small engines are 4-cycle. Left- and right-handed engines driving the same generator under automatic control are shown, and there are increasing numbers of automatic and multi-unit plants. Combination steam-diesel plants are also on the increase, as are emergency and standby diesel plants.

Many more manufacturers have cooperated in preparation of this table than in any previous one, and have also supplied us with detailed information of the types and sizes of engines they produce, for inclusion in the table on the next page, which this year for the first time shows engines classified by cylinder bore and stroke.

MANUFACTURERS & SUPPLIERS

ALLIS-CHALMERS MFG. CO.
Milwaukee, Wis.
4-cycle, electric-ignition, vertical
4-cyl., 70-hp. @ 1050 rpm. 5¼ x 6½
6-cyl., 110-hp. @ 1050 rpm. 5¼ x 6½

AMERICAN DIESEL ENGINE CO.
Oakland, California
4-cycle vertical
2-cyl., 35-hp. @ 1200 rpm. 5½ x 7
4-cyl., 75-hp. @ 1200 rpm. 5½ x 7
6-cyl., 125-hp. @ 1250 rpm. 5½ x 7

AMERICAN LOCOMOTIVE CO.
Diesel Engine Div.
30 Church St., New York, N. Y.
McIntosh & Seymour 4-cycle, vertical
6 & 8 cyl., 310 & 415 hp. @ 720 rpm. 9½ x 10½
6 & 8 cyl., 540 & 720 hp. @ 600 rpm. 12½ x 13
3-8 cyl., 225- 600 hp. @ 360 rpm. 12½ x 18
3-8 cyl., 230- 615 hp. @ 300 rpm. 12½ x 22
3-8 cyl., 430-1145 hp. @ 257 rpm. 17½ x 25
Alco-Sulzer, 2-cycle, vertical
4-8 cyl., 450 -900 hp. @ 327 rpm. 11½ x 19½
4-10 cyl., 720-1800 hp. @ 277 rpm. 14x 23½

AMERICAN M.A.N. CORP.
40 Rector St., New York, N. Y.
2-cycle vertical
4-10 cyl., 412-1065 hp. @ 375-400 rpm. 11¾ x 16½
4-10 cyl., 1310-3600 hp. @ 220-250 rpm. 20½ x 27½
2-cycle, double-acting, vertical
3-10 cyl., 2250-7650 hp. @ 167 rpm. 23⅝ x 35½
3-9 cyl., 3000-9000 hp. @ 115 rpm. 27½ x 47¼
6-9 cyl., 9600-14400 hp. @ 105 rpm. 39 x 55
4-cycle vertical
3-6 cyl., 42-85 hp. @ 1200 rpm. 4¾ x 7⅛
3 &6 cyl., 55 & 110 hp. @ 1000 rpm. 5⅛ x7⅛
3-8 cyl., 80-265 hp. @ 1000 rpm. 6⅞ x8¼
3-8 cyl., 115-310 hp. @ 500 rpm. 8¼ x 13
5-8 cyl., 215-350 hp. @ 650 rpm. 8¼ x 11¼
3-8 cyl., 190-510 hp. @ 375 rpm. 11¼ x 16½
5-10 cyl., 490-980 hp. @ 600 rpm. 11¼ x 15
5-8 cyl., 635-1015 hp. @ 350 rpm. 14⅜ x 21⅝
6-8 cyl., 995-1330 hp. @ 250 rpm. 17¾ x 26
6-8 cyl., 1280-1710 hp. @ 215 rpm. 20⅞ x 29½
6-8 cyl., 1740-2320 hp. @ 187 rpm. 24 x 33

ANDERSON ENGINE & FOUNDRY CO.
215 Jackson St., Anderson, Ind.
2-cycle vertical
1-6 cyl., 25-150 hp. @ 360 rpm. 8½ x 14
1-6 cyl., 35-210 hp. @ 360 rpm. 10 x 14
1-6 cyl., 60-360 hp. @ 300 rpm. 12½ x 18
1-6 cyl., 75-450 hp. @ 300 rpm. 14 x 18

ATLAS IMPERIAL DIESEL ENGINE CO.
19th Ave., Oakland, Calif.
4-cycle vertical
2 & 4 cyl., 18 & 40 hp. @ 1000 rpm. 4¾ x 6½
3-6 cyl., 45-90 hp. @ 700 rpm. 6 x 8
2-4 cyl., 30-60 hp. @ 600 rpm. 6½ x 8½
4 & 6 cyl., 80 & 120 hp. @ 650 rpm. 7 x 8½
3-6 cyl., 60-120 hp. @ 450 rpm. 7½ x 10½
6 & 8 cyl., 200 & 275 hp. @ 514 rpm. 9 x 10½
3-6 cyl., 80-160 hp. @ 360 rpm. 9 x 12
3-6 cyl., 105-210 hp. @ 360 rpm. 10 x 13
3-6 cyl., 150-300 hp. @ 327 rpm. 11½ x 15
3-6 cyl., 200-400 hp. @ 327 rpm. 13 x 16
6 cyl., 525 hp. @ 300 rpm. 14½ x 18

BOLINDERS CO., INC.
33 Rector St., New York, N. Y.
2-cycle vertical
1-2 cyl., 10-20 hp. @ 900-1000 rpm. 4¾ x 4¾
1-cyl., 25-hp. @ 800-900 rpm. 7⅛ x 7⅛
2-cyl., 50-hp. @ 800-900 rpm. 7⅛ x 7⅛
4-cyl., 100-hp. @ 800-900 rpm. 7⅛ x 7⅛
2-cyl., 70-hp. @ 450 rpm. 10⅝ x 11
2-cyl., 90-hp. @ 425 rpm. 11¾ x 12⅞

BRONANDER DIESEL ENGINE CO.
North Arlington, N. J.
V, opposed-piston, 10-hp., 750-1500 rpm.

BROMFIELD MFG. CO. INC.
211 Northern Ave., Boston, Mass.
2-cycle vertical
1-cyl., 12 hp. @ 750 rpm. 4⅛ x 6¾
2-cyl., 25 hp. @ 750 rpm. 4⅛ x 6¾
2-cyl., 50 hp. @ 500 rpm. 6¾ x 9⅞
4-cycle horizontal
1-cyl., 5 hp. @ 1500 rpm. 3⅜ x 4⅜
1-cyl., 7 hp. @ 1100 rpm. 3⅜ x 5½
1-cyl., 10 hp. @ 1000 rpm. 4¾ x 6⅞
4-cycle vertical
1-cyl., 16 hp. @ 1200 rpm. 4⅛ x 6⅝

BUCKEYE MACHINE CO.
Lima, Ohio
4-cycle vertical
1-5 cyl., 20-100 hp. @ 514 rpm. 7⅛ x 10½
2-8 cyl., 75-300 hp. @ 400 rpm. 9½ x 14
4-8 cyl., 300-600 hp. @ 360 rpm. 13½ x 15½

THE BUDA COMPANY
Harvey, Illinois
4-cycle vertical
4-cyl., 37-hp. @ 1700 rpm. 3⅝ x 4½
4-cyl., 47-hp. @ 1800 rpm. 3⅝ x 4¾
6-cyl., 66-hp. @ 1800 rpm. 3½ x 4¾
6-cyl., 90-hp. @ 1600 rpm. 4 x 5½
6-cyl., 100-hp. @ 1600 rpm. 4¼ x 5½
6-cyl., 123-hp. @ 1300 rpm. 4¾ x 6½
6-cyl., 155-hp. @ 1200 rpm. 5¼ x 7
6-cyl., 204-hp. @ 1000 rpm. 6¼ x 8¾
6-cyl., 220-hp. @ 1000 rpm. 6½ x 8¾

BUSCH-SULZER BROS. DIESEL ENGINE CO.
2nd & Utah Sts., St. Louis, Mo.
2-cycle vertical
4-8 cyl., 700-1400 hp. @ 300 rpm. 15⅛ x 21
4-10 cyl., 1200-3000 hp. @ 240 rpm. 19½ x 27
4-12 cyl., 2880-8640 hp. @ 150 rpm. 30 x 42
4-cycle vertical
3-8 cyl., 375-1000 hp. @ 300 rpm. 16¼ x 21
3-8 cyl., 375-1000 hp. @ 257 rpm. 16¼ x 24½
3-8 cyl., 405-1080 hp. @ 277 rpm. 16¼ x 24½
3-6 cyl., 300-600 hp. @ 225 rpm. 16¼ x 23
3-6 cyl., 339-678 hp. @ 257 rpm. 16¼ x 23
A. E. G. License

CATERPILLAR TRACTOR CO.
Peoria, Ill.
4-cycle vertical
3-8 cyl., 45-160 hp. @ 850 rpm. 5¾ x 8
4 cyl., 35-44 hp. @ 1400 rpm. 4¼ x 5½

CHICAGO PNEUMATIC TOOL CO.
6 East 44th St., New York, N. Y.
4-cycle, V, 80-800 hp. @ 257-400 rpm.

CLARK BROTHERS CO.
Olean, N. Y.
2-cycle horizontal
40-165 hp., 180-300 rpm.

CONSOLIDATED SHIPBUILDING CORP.
Morris Heights, N. Y. C.
4-cycle vertical marine engine
6-cyl., 200-300 hp. @ 500-700 rpm. 8½ x 11

CONTINENTAL MOTORS
Detroit, Mich.
2-cycle, R, 225-450 hp. @ 900 rpm.
Railroad primarily

COOPER-BESSEMER CORP.
Mt. Vernon, Ohio
4-cycle vertical
3-8 cyl., 80-210 hp. @ 514 rpm. 8 x 10½
3-8 cyl., 100-270 hp. @ 450 rpm. 9 x 12
3-8 cyl., 135-375 hp. @ 400 rpm. 10½ x 13½
3 & 4 cyl., 165 & 200 hp. @ 360 rpm. 11½ x 15
6 & 8 cyl., 335 & 450 hp. @ 400 rpm. 11½ x 15
6-8 cyl., 675-885 hp. @ 277 rpm. 15½ x 22
3-8 cyl., 420-1170 hp. @ 257 rpm. 18 x 22

COVIC DIESEL ENGINE CO.
923 E. San Fernando Blvd.
Burbank, Calif.
Engine under development

CUMMINS ENGINE CO.
Columbus, Ind.
4-cycle vertical
6-cyl., 85 hp. @ 2400 rpm. 4 x 5
4-cyl., 25-50 hp. @ 600-1200 rpm. 4⅛ x 6
6-cyl., 39-115 hp. @ 600-1800 rpm. 4⅛ x 6
4-cyl., 63-98 hp. @ 514-800 rpm. 6¾ x 9
6-cyl., 95-185 hp. @ 514-1000 rpm. 6¾ x 9
4-cyl., 67-105 hp. @ 514-800 rpm. 7 x 9
6-cyl., 100-195 hp. @ 514-1000 rpm. 7 x 9
3-cyl., 57-89 hp. @ 514-800 rpm. 7 x 10
4-cyl., 75-118 hp. @ 514-800 rpm. 7 x 10
6-cyl., 114-222 hp. @ 514-1000 rpm. 7 x 10
4-cycle Vee-type
12-cyl., 228-444 hp. @ 514-1000 rpm. 7 x 10

De La VERGNE ENGINE CO.
Paschall P. O., Philadelphia, Pa.
4-cycle vertical
6 & 8 cyl., 180-240 hp. @ 1200 rpm. 7 x 8
4-8 cyl., 180-360 hp. @ 600 rpm. 9 x 12
4-8 cyl., 320-640 hp. @ 450 rpm. 12½ x 15½
3-8 cyl., 240-640 hp. @ 300 rpm. 15 x 18½
5-8 cyl., 625-1000 hp. @ 240 rpm. 17½ x 24
5-8 cyl., 1000-1600 hp. @ 200 rpm. 22 x 30

DIESEL DYNAMICS CORP.
Woolworth Bldg., New York, N. Y.,
and
NORTHERN PRODUCTS CORP.
200 Pell St. Dock, Seattle, Wash.
Deutz Agents
2-cycle horizontal
2-cyl., 100-120 hp. @ 250-300 rpm. 8½ x 12⅞
2-cyl., 150-160 hp. @ 215-230 rpm. 14⅞ x 23⅝
2-cycle vertical
1-2 cyl., 8-25 hp. @ 520-750 rpm. 4¼ x 6¼
2-cyl., 25-36 hp. @ 420-600 rpm. 5¼ x 8¼
2-cyl., 40-50 hp. @ 400-500 rpm. 6⅞ x 9⅞
2-4 cyl., 60-145 hp. @ 370-450 rpm. 8⅞ x 11¼
4-cycle horizontal
1-cyl., 5-8 hp. @ 800-1250 rpm. 3¼ x 5½
1-cyl., 8-10 hp. @ 800-1000 rpm. 4¾ x 6⅞
1-cyl., 12-15 hp. @ 600-750 rpm. 5¼ x 8¼
1-cyl., 15-18 hp. @ 450-540 rpm. 6¼ x 11⅞
1-cyl., 20-25 hp. @ 400-480 rpm. 7½ x 12⅝
1-2 cyl., 25-60 hp. @ 350-420 rpm. 8¼ x 14⅞
1-2 cyl., 35-80 hp. @ 350-400 rpm. 9⅞ x 15
4-cycle vertical
1-2 cyl., 6-17 hp. @ 1000-1500 rpm. 3⅛ x 5⅛
2-cyl., 25 hp. @ 1200 rpm. 4⅞ x 5⅞
1-8 cyl., 11-150 hp. @ 1000-1500 rpm. 4⅞ x 6¼
2-6 cyl., 37-150 hp. @ 750-900 rpm. 6¼ x 7⅞
3-8 cyl., 80-270 hp. @ 600-750 rpm. 7⅞ x 9⅞
2-4 cyl., 75-125 hp. @ 375-450 rpm. 7½ x 15¼
3-8 cyl., 112-400 hp. @ 375-500 rpm. 9⅞ x 14⅞
3-8 cyl., 190-570 hp. @ 375-428 rpm. 11 x 17¼
6-8 cyl., 500-750 hp. @ 215-250 rpm. 14⅞ x 22¼
4-8 cyl., 500-1100 hp. @ 250-273 rpm. 15¾ x 26
Double-ended and supercharged units.

ELECTRIC BOAT CO.
Groton, Conn.
4-cycle vertical
6-cyl., 250 hp. @ 350 rpm. 10½ x 15
6-cyl., 350 hp. @ 280 rpm. 12½ x 18
6-cyl., 550 hp. @ 250 rpm. 15 x 22
8-cyl., 735 hp. @ 250 rpm. 15 x 22
All marine

ENTERPRISE DIESEL ENGINE CO.
18th & Alabama Sts., San Francisco, Calif.
4-cycle vertical
3-8 cyl., 40-200 hp. @ 500 rpm. 8 x 10
4-6 cyl., 100-250 hp. @ 350 rpm. 10 x 13
6-8 cyl., 250-450 hp. @ 400 rpm. 11½ x 14
6-8 cyl., 250-500 hp. @ 360 rpm. 12 x 15
6-8 cyl., 500-900 hp. @ 300 rpm. 16 x 20

F.A.B. MANUFACTURING CO.
67th & Vallejo Sts., Oakland, Calif.
2-cycle vertical
1-cyl., 10-hp. @ 700 rpm. 5¾ x 6
1-cyl., 15-hp. @ 650 rpm. 6¾ x 7¼
1-cyl., 25-hp. @ 550 rpm. 8 x 9¼
2-cyl., 50-hp. @ 550 rpm. 8 x 9¼
1-cyl., 30-hp. @ 500 rpm. 9 x 10
2-cyl., 60-hp. @ 500 rpm. 9 x 10
1-cyl., 40-hp. @ 450 rpm. 10¼ x 11
2-cyl., 80-hp. @ 450 rpm. 10¼ x 11

FAIRBANKS, MORSE & CO.
900 S. Wabash Ave., Chicago, Ill.

2-cycle vertical
1-3 cyl., 60-180 hp. @ 360 rpm. 12 x 15
1-6 cyl., 75-450 hp. @ 300 rpm. 14 x 17
2-6 cyl., 60-180 hp. @ 450 rpm. 8¾ x 10½
4-6 cyl., 160-240 hp. @ 400 rpm. 10 x 12½
5-7 cyl., 250-360 hp. @ 360 rpm. 10½ x 12½
5-7 cyl., 500-700 hp. @ 400 rpm. 12 x 15
5-7 cyl., 575-805 hp. @ 300 rpm. 14 x 17
5-8 cyl., 875-1400 hp. @ 300 rpm. 16 x 20

4-cycle vertical
1-6 cyl., 8-48 hp. @ 1200 rpm. 4¼ x 6
4-6 cyl., 60-120 hp. @ 900 rpm. 5½ x 7½

FRANKLIN VALVELESS ENGINE CO.
Franklin, Pa.

2-cycle horizontal
1-cyl., 25-hp. @ 260 rpm. 11½ x 12
1-cyl., 30-hp. @ 260 rpm. 12 x 12
1-cyl., 35-hp. @ 240 rpm. 13 x 13
1-cyl., 40-hp. @ 240 rpm. 12 x 16
1-cyl., 50-hp. @ 240 rpm. 14 x 15
1-cyl., 65-hp. @ 260 rpm. 15 x 15

FULTON IRON WORKS
6400 Gambleton Pl., St. Louis, Mo.
4-cycle engines, V, up to 1800 hp.

GENERAL MOTORS CORP.
Diesel Engine Div., Detroit, Mich.
4-cycle, 1-6 cyl., 20-160 hp.

HERCULES MOTORS CORP.
Canton, Ohio.

4-cycle vertical
6-cyl., 77-hp. @ 2600 rpm. 3½ x 4½
6-cyl., 83-hp. @ 2600 rpm. 3¾ x 4½
6-cyl., 120-hp. @ 2000 rpm. 4⅜ x 5¼
6-cyl., 160-hp. @ 1600 rpm. 5 x 6

HILL DIESEL ENGINE CO.
Lansing, Mich.

4-cycle vertical
4-cyl., 30-hp. @ 1200 rpm. 3½ x 6
6-cyl., 45-hp. @ 1200 rpm. 3½ x 6
1-cyl., 11-hp. @ 720 rpm. 5 x 7
2-cyl., 22-hp. @ 720 rpm. 5 x 7
3-cyl., 32-hp. @ 720 rpm. 5 x 7
4-cyl., 43-hp. @ 720 rpm. 5 x 7
6-cyl., 65-hp. @ 720 rpm. 5 x 7
4-cyl., 70-hp. @ 720 rpm. 6 x 10
6-cyl., 106-hp. @ 720 rpm. 6 x 10

F. VAN ROSSEN HOOGENDYK
Graybar Bldg., New York, N. Y.
Representing M. W. M., Mercedes-Benz and Kromhout

HOOVEN, OWENS, RENTSCHLER DIV.
General Machinery Corporation
Hamilton, Ohio

2-cycle vertical
1200-12,000 hp. @ 120-250 rpm.
Also marine engines (M. A. N. License)

INGERSOLL-RAND CO.
Phillipsburg, N. J.

4-cycle vertical
3 & 4 cyl., 150 & 200 hp. @ 514 rpm. 10 x 12
5-8 cyl., 290-460 hp. @ 600 rpm. 10 x 12
3-8 cyl., 175-450 hp. @ 360 rpm. 11 x 18
3-8 cyl., 260-700 hp. @ 300 rpm. 13¼ x 22
3-8 cyl., 375-1000 hp. @ 277 rpm. 16 x 24
6-8 cyl., 1125-1500 hp. @ 240 rpm. 19½ x 28

INTERNATIONAL HARVESTER CO.
606 S. Michigan Ave., Chicago, Ill. (No data)

JOHNSON MANUFACTURING CO.
Fox & Holly Sts., Seattle, Wash.

2-cycle vertical
25-200 hp., 350-600 rpm.

4-cycle vertical
35-105 hp., 500 rpm.

KAHLENBERG BROS. CO.
Two Rivers, Wis.

2-cycle vertical
15-200 hp., 300-450 rpm.

MARKEY MACHINERY CO., INC.
85 Horton St., Seattle, Wash.

2-cycle vertical
12-32 hp., 425-450 rpm.

MASON DIESEL ENGINE CO.
3851-55 Santa Fe Ave., Los Angeles, Calif.

4-cycle vertical
7½-75 hp., 950-1750 rpm.

MUNCIE OIL ENGINE CO.
Muncie, Ind.

2-cycle engines
V, 45-360 hp., 300-257 rpm.
H, 10-125 hp., 350-190 rpm.

MURPHY DIESEL CO., LTD.
5317 W. Burnham St., Milwaukee, Wis.

4-cycle vertical
6-cyl., 150-hp. @ 1200 rpm. 5¾ x 6½
4-cyl., 100 hp. @ 1200 rpm. 5¾ x 6½

NATIONAL SUPPLY CO. OF DELAWARE
Superior Engine Div.
Holmesburg, Philadelphia, Pa.
and Springfield, Ohio

4-cycle vertical
2-cyl., 28-hp. @ 1400 rpm. 4½ x 5¾
4-cyl., 62-hp. @ 1500 rpm. 4½ x 5¾
6-cyl., 100-hp. @ 1600 rpm. 4½ x 5¾
8-cyl., 150-hp. @ 1800 rpm. 4½ x 5¾
3-8 cyl., 65-180 hp. @ 700 rpm. 7 x 9
3-8 cyl., 130-350 hp. @ 600 rpm. 9 x 12
4-6 cyl., 220-330 hp. @ 400 rpm. 11½ x 14
3-8 cyl., 210-560 hp. @ 400 rpm. 12½ x 15
4-8 cyl., 405-810 hp. @ 360 rpm. 14½ x 18

NORDBERG MFG. CO.
Milwaukee, Wis.

2-cycle vertical
3-8 cyl., 650-2000 hp. @ 225-257 rpm.
4-8 cyl., 1500-3000 hp. @ 225 rpm.
4-8 cyl., 3000-7250 hp. @ 150 rpm.
Burmeister & Wain License

4-cycle vertical
3-8 cyl., 150-450 hp. @ 400-450 rpm.
3-8 cyl., 375-1000 hp. @ 300-327 rpm.

PAGE ENGINEERING CO.
Clearing P. O., Chicago, Ill.

4-cycle horizontal
60-240 hp. 400 rpm.

PEET & POWERS, INC.
70 East 45th St., New York, N. Y.
Lister and Ruston engines

4-cycle vertical
1-4 cyl., 3-40 hp. @ 1200 rpm. 4½ x 5½
1-2 cyl., 3-10 hp. @ 600 rpm. 4½ x 5½
1-8 cyl., 60-1200 hp. 900-400 rpm. 5-14 x 8-20

4-cycle horizontal
1-4 cyl., 7-260 hp. 290 rpm. 5-13 x 9-22

PIONEER EQUIPMENT CORP. OF AMERICA
Woolworth Building, New York, N. Y.
Krupp and Schlueter engines
2-cycle, V, 1230-10, 100 hp. 200-97 rpm.
4-cycle, V, 58-2500 hp. 200-900 rpm.

POWER MANUFACTURING CO.
Marion, Ohio

2-cycle engines
V & H, to 185 hp., 327 rpm.

RATHBUN-JONES ENGINEERING CO.
823 Spencer St., Toledo, Ohio
(See Ingersoll-Rand Co., Phillipsburg, N. J.)

RED WING MOTOR CO.
Red Wing, Minn.

4-cycle vertical
4-cyl., 35-40 hp. @ 1400 rpm. 3¾ x 4¾
4-cyl., 55-60 hp. @ 1500 rpm. 4½ x 5
6-cyl., 65-75 hp. @ 1800 rpm. 3¾ x 4¾
4-cyl., 80-90 hp. @ 1050 rpm. 6 x 6½
6-cyl., 75-100 hp. @ 1500 rpm. 4⅜ x 5½
6-cyl., 120-140 hp. @ 1500 rpm. 5 x 5½
6-cyl., 160-180 hp. @ 1050 rpm. 6½ x 7
6-cyl., 180-200 hp. @ 1050 rpm. 7 x 7
Comet & Hesselman Licenses

JOSEPH REID GAS ENGINE CO.
Oil City, Pa.

2-cycle horizontal
25-150 hp. 190-400 rpm.

STANDARD DIESEL ENGINE CO.
150 Whiton St., Jersey City, N. J.

4-cycle vertical
1-8 cyl., 15-120 hp. @ 600 rpm. 6 x 8
3-8 cyl., 75-200 hp. @ 360 rpm. 8½ x 12
6 & 8 cyl., 220 & 295 hp. @ 327 rpm. 10 x 14
6 & 8 cyl., 285 & 375 hp. @ 327 rpm. 11 x 15
6 & 8 cyl., 375 & 500 hp. @ 327 rpm. 12 x 17
6 & 8 cyl., 445 & 590 hp. @ 300 rpm. 13½ x 71

STERLING ENGINE CO.
1250 Niagara St., Buffalo, N. Y.

2-cycle, opposed-piston engines
4-cyl.*, 135-hp. @ 1200 rpm. 4.25 x 5.45
4-cyl.*, 150-hp. @ 1200 rpm. 4.50 x 5.45
* 8 pistons (Michell patents)

STOVER MFG. & ENGINE CO.
Freeport, Illinois

4-cycle vertical
1-cyl., 5-hp. @ 1200 rpm. 3⅞ x 5¼
1-cyl., 7½-hp. @ 1200 rpm. 4¼ x 5¼
1-cyl., 10-hp. @ 1000 rpm. 5 x 6½
1-cyl., 15-hp. @ 1000 rpm. 5½ x 6½
Acro license

SUN SHIPBUILDING & DRYDOCK CO.
Chester, Pa.
Marine engines

SUPERIOR ENGINE DIVISION
(See National Supply Co. of Del.)

TIPS ENGINE WORKS
Austin, Texas

2-cycle horizontal
1-cyl., 40 hp., 12½ x 13
1-cyl., 25 hp., 10 x 11

TITUSVILLE IRON WORKS CO.
Titusville, Pa.

2-cycle horizontal and vertical
1-2 cyl., 25-350 hp. @ 180-350 rpm.
7½-16 x 10-18 in.

UNION DIESEL ENGINE CO.
Kennedy & E. 7th Sts., Oakland, Calif.

4-cycle vertical
2-6 cyl., 50-150 hp. @ 450 rpm. 8 x 11
3-6 cyl., 100-200 hp. @ 400 rpm. 9 x 13
3-6 cyl., 135-275 hp. @ 327 rpm. 11 x 15
4-8 cyl., 250-500 hp. @ 300 rpm. 12½ x 17
5-8 cyl., 500-800 hp. @ 257 rpm. 15½ x 20½

UNION MACHINE CO.
934 Brannan St., San Francisco, Calif.

2-cycle vertical
2-cyl., 65 hp. @ 375 rpm. 9 x 12
3-8 cyl., 100-270 hp. @ 375 rpm. 9 x 12

VENN-SEVERIN MACHINE CO.
1317 West North Ave., Chicago, Ill.

2-cycle vertical
1-2 cyl., 30-60 hp. @ 400 rpm. 10½ x 12
1-2 cyl., 40-85 hp. @ 300 rpm. 12¼ x 13½
2-cyl., 100 hp. @ 360 rpm. 12¼ x 13½
1-cyl., 60 hp. @ 277 rpm. 14¼ x 16½
2-4 cyl., 130-275 hp. @ 300 rpm. 14¼ x 16½
2-4 cyl., 140-300 hp. @ 327 rpm. 14¼ x 16½

WAUKESHA MOTOR CO.
Waukesha, Wis.

4-cycle vertical
4-cyl., 40-hp. @ 1800 rpm. 3¾ x 4¾
4-cyl., 60-hp. @ 1700 rpm. 4⅝ x 5¼
4-cyl., 85-hp. @ 1050 rpm. 6 x 6½
4-cyl., 110-hp. @ 1050 rpm. 6½ x 8
6-cyl., 150-hp. @ 950 rpm. 6½ x 7
6-cyl., 180-hp. @ 950 rpm. 7 x 7
6-cyl., 300-hp. @ 900 rpm. 8½ x 8½
Hesselman license

WASHINGTON IRON WORKS
1500 6th Ave., South, Seattle, Wash.

4-cycle vertical
2-6 cyl., 45-135 hp. @ 450 rpm. 8½ x 10
3-6 cyl., 80-160 hp. @ 400 rpm. 9 x 11½
3-6 cyl., 100-200 hp. @ 360 rpm. 10 x 12½
3-8 cyl., 120-320 hp. @ 360 rpm. 10¼ x 13½
3-8 cyl., 150-400 hp. @ 327 rpm. 11½ x 15
4-8 cyl., 240-480 hp. @ 300 rpm. 13 x 16
6 & 8 cyl., 450 & 600 hp. @ 270 rpm. 14½ x 18
6 & 8 cyl., 600 & 800 hp. @ 257 rpm. 16¾ x 20
6 & 8 cyl., 750 & 1000 hp. @ 225 rpm. 18 x 24

WEBER ENGINE CO.
12th & Winchester Sts., Kansas City, Mo.

2-cycle vertical
2-cyl., 40-hp. @ 400 rpm. 7½ x 9
2-cyl., 50-hp. @ 400 rpm. 7½ x 9

2-cycle horizontal
1-cyl., 25-hp. @ 180 rpm. 10¼ x 14
1-cyl., 30-hp. @ 180 rpm. 11 x 14
1-cyl., 35-hp. @ 180 rpm. 12 x 14
1-cyl., 40-hp. @ 180 rpm. 13 x 14
1-cyl., 50-hp. @ 180 rpm. 14 x 14
All engines convertible to gas

WESTERN ENGINE CORP.
1000 Alhambra Ave., Los Angeles, Calif.

4-cycle vertical
2-6-cyl., 50-150 hp. @ 750 rpm. 7¼ x 8
2-6-cyl., 100-300 hp. @ 500 rpm. 11 x 12

WINTON ENGINE CORP.
2160 W. 106th St., Cleveland, Ohio.
Marine and Railroad Engines (See General Motors)

WITTE ENGINE WORKS
1600 Oakland Ave., Kansas City, Mo.

4-cycle horizontal
1-cyl., 5-hp. @ 850 rpm. 4¼ x 6
1-cyl., 10-hp. @ 720 rpm. 5 x 8

4-cycle vertical
1-cyl., 3-hp. @ 1200 rpm. 3¼ x 4

WOLVERINE MOTOR WORKS, INC.
Bridgeport, Conn.

2-cycle vertical
2-5 cyl., 25-90 hp. @ 425-500 rpm. 6⅝ x 8⅝

4-cycle vertical
2-4 cyl., 50-120 hp. @ 360-400 rpm. 8½ x 12½
2-6 cyl., 65-225 hp. @ 360-400 rpm. 9¼ x 14
Also marine engines

WORTHINGTON PUMP & MACHINERY CORP.
Harrison, N. J.

4-cycle vertical
2-6 cyl., 25-75 hp. @ 514 rpm.
2-6 cyl., 30-90 hp. @ 600 rpm.
3-6 cyl., 50-100 hp. @ 400 rpm.
3-6 cyl., 75-150 hp. @ 327 rpm.
3-8 cyl., 125-375 hp. @ 327 rpm.

LISTINGS are as complete and accurate as available information permits, but *Power* assumes no responsibility for errors or omissions. Almost all listings supplied by manufacturers. Abbreviations are: cyl. — cylinder, V — vertical, H — horizontal, R — radial. Two numbers at end of each line are respectively bore and stroke in inches.

In listing number of cylinders, the hyphen (5-8) means that intermediate numbers of cylinders give intermediate horsepowers in even steps, the "and" sign (6 & 8) means that only the two sizes are available.

Diesel PLANT ACCESSORY and SUPPLY MANUFACTURERS

ACOUSTIC MATERIALS
(See also Isolation)
Armstrong Cork Products Co., Lancaster, Pa.
Burgess Battery Co., Madison, Wis.
Johns Manville, New York, N. Y.

AIR BOTTLES
Alco Products, Inc., N. Y. C.
M. W. Kellogg Co., N. Y. C.
A. O. Smith Corp., Milwaukee

ALARM SYSTEMS
Delco-Remy Corp., Anderson, Ind.
Diesel Plant Specialties Co., Chicago, Ill.
Federal Electric Co., Chicago, Ill.
Ill. Testing Labs., Inc., Chicago.
Klaxon Co., Anderson, Ind.
Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
Electric Auto-Lite Co., Moto Meter Gauge & Equipt. Div., N. Y. C.
Viking Instruments, Inc., N. Y. C.

ANALYZERS, EXHAUST GAS
Bacharach Ind. Inst. Co., Pittsburgh.
Hays Corp., Michigan City, Ind.

BATTERIES, STORAGE
Electric Storage Battery Co., Philadelphia, Pa.
Gould Storage Battery Co., Depew, N. Y.
Philadelphia Storage Battery Co., Philadelphia, Pa.
Thomas A. Edison, Inc., West Orange, N. J.
U. S. L. Battery Corp., Niagara Falls, N. Y.
Willard Storage Battery Co., Cleveland, Ohio.

BEARINGS, ANTI-FRICTION
Aetna Ball Bearing Mfg. Co., Chicago, Ill.
Ahlberg Bearing Co., Chicago, Ill.
Bantam Ball Bearing Corp., South Bend, Ind.
Fafnir Bearing Co., New Britain, Conn.
Hyatt Roller Bearing Co., Harrison, N. J.
New Departure Div., General Motors Corp., Bristol, Conn.
Norma-Hoffman Bearings Corp., Stamford, Conn.
SKF Industries, Inc., Philadelphia.
Timken Roller Bearing Co., Canton, Ohio.

BEARINGS, BABBIT-LINED
American Bearing Corp., Indianapolis.
Beckett Bronze Co., Muncie, Ind.
Federal-Mogul Corp., Detroit, Mich.
Westinghouse Electric & Mfg Co., East Pittsburgh, Pa.

BELTING, FLAT TRANSMISSION
Alexander Bros. Inc., Philadelphia.
W. D. Allen Mfg. Co., Chicago.
Boston Woven Hose & Rubber Co., Boston, Mass.
Chicago Rawhide Mfg. Co., Chicago.
Chicago Belting Co., Chicago, Ill.
B. F. Goodrich Co., Akron, Ohio.
Goodyear Tire & Rubber Co., Akron.
Graton & Knight Co., Worcester, Mass.
E. F. Houghton & Co., Philadelphia.
Manhattan Rubber Mfg. Div., Passaic, N. J.
New York Belting & Packing Co., New York, N. Y.
Chas. A. Schieren Co., N. Y. C.
Thermoid Co., Trenton, N. J.
Victor Balata Belting Co., Easton, Pa.
U. S. Rubber Co., New York, N. Y.

BELTING, V-TYPE
Allis-Chalmers Mfg. Co., Milwaukee.
Chicago Belting Co., Chicago, Ill.
Dayton Rubber Mfg. Co., Dayton, O.
Fairbanks, Morse & Co., Chicago.
Foote Gear Works, Chicago, Ill.
Gates Rubber Mfg. Co., Denver.
L. H. Gilmer Co., Philadelphia, Pa.
B. F. Goodrich Co., Akron, Ohio.
Goodyear Tire & Rubber Co., Akron.
Manhattan Rubber Mfg. Div., Passaic, N. J.
Rockwood Mfg. Co., Indianapolis.
Worthington Pump & Machinery Corp., Harrison, N. J.

BLOWERS, SUPERCHARGING & SCAVENGING
Allen Billmyre Corp., South Norwalk, Conn.
Allis-Chalmers Mfg., Co., Milwaukee.
American Blower Corp., Detroit
Coppus Engineering Corp., Worcester, Mass.
Elliott Co., Pittsburgh, Pa.
Ingersoll-Rand Co., New York, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
B. F. Sturtevant Co., Hyde Park, Mass.

BOILERS, WASTE-HEAT
Alco Products, Inc., N. Y. C.
Babcock & Wilcox Co., N. Y. C.
Bartlett Hayward Div., Baltimore.
Combustion Engineering Co., New York, N. Y.
Davis Engineering Corp., Elizabeth, N. J.
Edge Moor Iron Co., New York, N. Y.
Foster Wheeler Corp., N. Y. C.
Murray Iron Works Co., Burlington, Iowa.
The Sims Co., Erie, Pa.
Titusville Iron Works Co., Titusville, Pa.
Union Iron Works, Erie, Pa.
Henry Vogt Machine Co., Louisville.

CENTRIFUGES, OIL
Braun Corp., Los Angeles, Calif.
De Laval Separator Co., N. Y. C.
De La Vergne Engine Co., Phila.
Goulds Pumps, Inc., Seneca Falls, N. Y.
Sharples Specialty Co., Philadelphia.

CHAINS & CHAIN DRIVES
Baldwin-Duckworth Chain Corp., Springfield, Mass.
Chain Belt Co., Milwaukee, Wis.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Foote Gear Works, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., Chicago, Ill.
Morse Chain Co., Ithaca, N. Y.
Ramsey Chain Co., Inc., Albany, N. Y.
Whitney Mfg. Co., Hartford, Conn.

CLUTCHES
W. E. Caldwell Co., Inc., Louisville.
Cutler-Hammer, Inc., Milwaukee.
Dodge Mfg. Corp., Mishawaka, Ind.
F. A. B. Mfg. Co., Oakland, Calif.
Falk Corp., Milwaukee, Wis.
Foote Bros. Gear & Machine Co., Chicago.
Foote Gear Works, Chicago, Ill.
Hill Clutch Machine & Foundry Co., Cleveland, Ohio.
Hilliard Corp., Elmira, N. Y.
Kinney Mfg. Co., Boston, Mass.
Magnetic Mfg Co., Milwaukee, Wis.
The Medart Co., St. Louis, Mo.
Morse Chain Co., Ithaca, N. Y.
Reeves Pulley Co., Columbus, Ind.
Jos. Reid Gas Engine Co., Oil City, Pa.
Snow & Petrelli Mfg. Co., New Haven, Conn.
Twin Disc Clutch Co., Racine, Wis.

COCKS, CYLINDER
Consolidated Ashcroft Hancock Co. Inc., Bridgeport, Conn.
Crane Co., Chicago, Ill.
Jarecki Mfg. Co., Erie, Pa.
Lunkenheimer Co., Cincinnati, Ohio.
Wm. Powell Co., Cincinnati, Ohio.
Walworth Co., New York, N. Y.

COMPRESSORS, AIR
Allis-Chalmers Mfg. Co., Milwaukee.
Atlas-Imperial Diesel Engine Co., Oakland, Calif.
Binks Mfg. Co., Chicago, Ill.
Bolinders Co., Inc., N. Y. C.
Bury Compressor Co., Erie, Pa.
Curtis Pneumatic Machinery Co., St. Louis, Mo.
Chicago Pneumatic Tool Co., N. Y. C.
Fairbanks, Morse & Co., Chicago.
Fuller Co., Catasauqua, Pa.
Gardner-Denver Co., Quincy, Ill.
Hill Diesel Engine Co., Lansing, Mich.
Ingersoll-Rand Co., New York, N. Y.
Kahlenberg Bros. Co., Two Rivers, Wis.
Nash Engineering Co., South Norwalk, Conn.
Nordberg Mfg. Co., Milwaukee, Wis.
Norwalk Co., Inc., S. Norwalk, Conn.
Novo Engine Co., Lansing, Mich.
Pennsylvania Pump & Compressor Co., Easton, Pa.
Quincy Compressor Co., Quincy, Ill.
Jos. Reid Gas Engine Co., Oil City, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Sullivan Machinery Co., Chicago
Worthington Pump & Machinery Co., Harrison, N. J.

COMPRESSOR VALVES
Binks Mfg. Co., Chicago, Ill.
J. H. H. Voss, Inc., N. Y. C.
Worthington Pump & Machinery Co., Harrison, N. J.

CONNECTING RODS
Aluminum Co. of America, Pittsburgh, Pa.
Atlas Drop Forge Co., Lansing, Mich.
Bethlehem Steel Co., Bethlehem, Pa.
Erie Forge Co., Erie, Pa.
Heppenstall Co., Pittsburgh, Pa.
Mesta Machine Co., Pittsburgh, Pa.
National Forge & Ordnance Co., Irvine, Warren Co., Pa.
Park Drop Forge Co., Cleveland, O.
Wyman Gordon Co., Worcester, Pa.

CONTROL, AUTOMATIC
Automatic Diesel Electric, Inc., New York, N. Y.
Bromfield Mfg. Co., Inc., Boston
Diesel Utilities, Inc., N. Y. C.
Thermal Engineering Co., Boston

CONTROL, VOLTAGE
Allis-Chalmers Mfg. Co., Milwaukee
General Electric Co., Schenectady
Leeds & Northrup Co., Philadelphia
R. E. Swann & Co., Hanover, Pa.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

CONTROLLERS, TEMPERATURE
Bailey Meter Co., Cleveland, Ohio
The Bristol Co., Waterbury, Conn.
Foxboro Co., Foxboro, Mass.
Leeds & Northrup Co., Philadelphia
Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
Sarco Co., New York, N. Y.
Taylor Instrument Cos., Rochester, N. Y.
Thomas A. Edison, Inc., West Orange, N. J.

COOLERS, OIL
Alco Products, Inc., New York, N. Y.
Andale Co., Philadelphia, Pa.
Consolidated Steel Corp., Los Angeles
Croll-Reynolds Engineering Co., Inc., New York, N. Y.
Davis Engineering Corp., Elizabeth, N. J.
Foster Wheeler Corp., N. Y. C.
Griscom-Russell Co., N. Y. C.
Gross Mechanical Labs., Inc., Baltimore, Md.
G & O Mfg. Co., New Haven, Conn.
Harrison Radiator Div., Lockport, N. Y.
Heat Exchanger Co., Grove City, Pa.
Ingersoll-Rand Co., New York, N. Y.
Rome-Turney Radiator Co., Rome, N. Y.
The Sims Co., Erie, Pa.
Schutte & Koerting Co., Phila.
Tulsa Boiler & Machinery Co., Tulsa, Okla.
Henry Vogt Machine Co., Louisville
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Young Radiator Co., Racine, Wis.
Zenith Carburetor Corp., Detroit

COOLERS, JACKET-WATER
Alco Products, Inc., New York, N. Y.
Binks Mfg. Co., Chicago, Ill.
Foster Wheeler Corp., N. Y. C.
Harrison Radiator Div., Lockport, N. Y.
The Sims Co., Erie, Pa.
Tulsa Boiler & Machinery Co., Tulsa, Okla.
Young Radiator Co., Racine, Wis.

COOLING TOWERS
Alco Products, Inc., New York, N. Y.
Binks Mfg. Co., Chicago, Ill.
Cooling Tower Co., Inc., N. Y. C.
Foster Wheeler Corp., N. Y. C.
Harry Cooling & Equipt. Co., Doylestown, Pa.
Lilie-Hoffman Cooling Tower Co., Inc., St. Louis, Mo.
The Marley Co., Kansas City, Mo.
Penn Cooling Tower Co., Pittsburgh
J. F. Pritchard Co., Kansas City, Mo.
Schubert-Christy Co., Affton, Mo.
C. H. Wheeler Mfg. Co., Philadelphia

COUPLINGS
Ajax Flexible Coupling Co., Westfield, N. Y.
Allis-Chalmers Mfg. Co., Milwaukee
Bartlett Hayward Div., Baltimore.
Boston Gear Works, Inc., N. Quincy, Mass.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Erie Clutch & Pulley Co., Erie, Pa.
F. A. B. Mfg. Co., Oakland, Calif.
Fairbanks, Morse & Co., Chicago
Falk Corp., Milwaukee, Wis.
Farrell-Birmingham Co., Inc., Ansonia, Conn.
Foote Gear Works, Chicago, Ill.
General Electric Co., Schenectady
The Hilliard Corp., Elmira, N. Y.
Link-Belt Co., Chicago, Ill.
Lovejoy Tool Works, Chicago, Ill.
Morse Chain Co., Ithaca, N. Y.
Thomas Flexible Coupling Co., Warren, Pa.
John Waldron Corp., New Brunswick, N. J.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

CRANKSHAFTS
Atlas Drop Forge Co., Lansing, Mich.
Atlas Forgings Co., Cicero, Ill.
Bethlehem Steel Co., Bethlehem, Pa.
Camden Forge Co., Camden, N. J.
Erie Forge Co., Erie, Pa.
Muskegon Motor Specialties Co., Jackson, Mich.
National Forge & Ordnance Co., Irvine, Warren Co., Pa.
Ohio Crankshaft Co., Cleveland, O.
Park Drop Forge Co., Cleveland, O.
Titusville Forge Co., Titusville, Pa.
Washington Iron Works, Sherman, Texas (Repair)
Wyman Gordon Co., Worcester, Mass.

CYLINDER HONING TOOLS
Carborundum Co., Hutto Machine Div., Detroit, Mich.
Barnes Drill Co., Rockford, Ill.
Micromatic Hone Corp., Detroit

DRIVES
(See also Reducers, Gearing, etc.)
Boston Gear Works, Inc., N. Quincy, Mass.
Diamond Chain & Mfg. Co., Indianapolis, Ind.
Fairbanks, Morse & Co., Chicago
The Medart Co., St. Louis, Mo.
Morse Chain Co., Ithaca, N. Y.
Reeves Pulley Co., Columbus, Ind.
Worthington Pump & Machinery Co., Harrison, N. J.

EXPANSION JOINTS
American District Steam Co., N. Tonawanda, N. Y.
E. B. Badger & Sons Co., Boston
Philip Carey Co., Lockland, Cincinnati, Ohio
Croll-Reynolds Engineering Co., Inc., New York, N. Y.
Direct Separator Co., Syracuse, N. Y.
Goodyear Tire & Rubber Co., Akron
Pennsylvania Metallic Tubing Co., Philadelphia, Pa.
Yarnall-Waring Co., Philadelphia

FILTERS, AIR
Air-Maze Corp., Cleveland, Ohio.
American Air Filter Co., Inc., Louisville, Ky.
Binks Mfg. Co., Chicago, Ill.
Burgess Battery Co., Madison, Wis.
Coppus Engineering Co,, Worcester, Mass.
Donaldson Co., Inc., St. Paul, Minn.
Fairbanks, Morse & Co., Chicago
Handy Governor Corp., Detroit
Independent Air Filter Co., Inc., Chicago, Ill.
Owens-Illinois Glass Co., Toledo, Ohio.
Skinner Purifiers, Inc., Detroit.
Staynew Filter Corp., Rochester, N. Y.
United Air Cleaner Corp., Chicago
Vortox Mfg. Co., Claremont, Calif.

FILTERS, OIL
S. F. Bowser & Co., Inc., Fort Wayne
Burt Mfg. Co., Akron, Ohio.
Cuno Engineering Corp., Meriden, Conn.
De Laval Separator Co., N. Y. C.
De La Vergne Engine Co., Phila.
Diesel Filter Co., Astoria, Ore.
Goulds Pumps, Inc., Seneca Falls, N. Y.
Handy Governor Corp., Detroit
Michiana Products Corp., Michigan City, Ind.

Motor Improvements, Inc., Newark, N. J.
Wm. W. Nugent & Co., Inc., Chicago
Neptune Meter Co., New York, N. Y.
Schutte & Koerting Co., Philadelphia
Skinner Purifiers, Inc., Detroit
Staynew Filter Corp., Rochester, N. Y.
United American Bosch Corp., Springfield, Mass.
Zenith Carburetor Corp., Detroit

FILTERS, WATER
Cochrane Corp., Philadelphia, Pa.
Elgin Softener Corp., Elgin, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., Chicago
Loomis-Manning Filter Mfg. Co., Philadelphia, Pa.
Permutit Co., New York, N. Y.
Power Plant Specialty Co., Chicago
Zeolite Engineering Corp., Chicago

FREQUENCY CONTROL
General Electric Co., Schenectady
Leeds & Northrup Co., Philadelphia
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Woodward Governor Co., Rockford, Ill.

GAGES, PRESSURE
Ashton Valve Co., Cambridge, Mass.
Bacharach Industrial Instruments Co., Pittsburgh, Pa.
Binks Mfg. Co., Chicago, Ill.
Consolidated Ashcroft Hancock Co., Inc., Bridgeport, Conn.
Esterline-Angus Co., Indianapolis
Foxboro Co., Foxboro, Mass.
Hays Corp., Michigan City, Ind.
Electric Auto-Lite Co., Moto Meter Gauge & Equipt. Div., N. Y. C.
Marshalltown Mfg. Co., Marshalltown, Iowa.
Rochester Mfg. Co., Inc., Rochester, N. Y.
U. S. Gauge Co., New York, N. Y.
Viking Instruments, Inc., N. Y. C.

GAGES & METERS, RECORDING
Ashton Valve Co., Cambridge, Mass.
Bailey Meter Co., Cleveland, Ohio.
Bristol Co., Waterbury, Conn.
Brown Instrument Co., Philadelphia
Consolidated Ashcroft Hancock Co., Inc., Bridgeport, Conn.
Defender Automatic Regulator Co., St. Louis, Mo
Foxboro Co., Foxboro, Mass.
Hays Corp., Michigan City, Ind.
Leeds & Northrup Co., Philadelphia
Jas. P. Marsh Corp., Chicago, Ill.
Electric Auto-Lite Co., Moto Meter Gauge & Equipt. Div., N. Y. C.
Republic Flow Meters Co., Chicago
C. J. Tagliabue Mfg. Co., Brooklyn
Taylor Instrument Cos., Rochester, N. Y.
U. S. Gauge Co., New York, N. Y.

GAGES, STRAIN OR CRANKSHAFT
Baldwin-Southwark Corp., Phila.
Hartford Steam Boiler Inspection & Insurance Co., Hartford, Conn.
L. S. Starrett Co., Athol, Mass.

GAGES, TANK
Binks Mfg. Co., Chicago, Ill.
W. E. Caldwell Co., Inc., Louisville
Detroit Lubricator Co., Detroit
Foxboro Co., Foxboro, Mass.
King-Seeley Corp., Ann Arbor, Mich.
Leeds & Northrup Co., Philadelphia
Liquidometer Corp., Long Island City, N. Y.
Lunkenheimer Co., Cincinnati, Ohio
Morey-Jones Ltd., Los Angeles
Petrometer Corp., Long Island City, N. Y.
Pneumercator Co., Inc., N. Y. C.
Rochester Mfg. Co., Inc., Rochester, N.Y.
Uehling Instrument Co., Paterson, N. J.
Viking Pump Co., Cedar Falls, Iowa

GASKETS & PACKING
Acme Mfg. & Gasket Co., Phila.
Akron Metallic Gasket Co., Akron, Ohio
Anchor Packing Co., Philadelphia
Belmont Packing & Rubber Co., Philadelphia, Pa.
A. W. Chesterton Co., Boston, Mass.
Chicago-Wilcox Mfg. Co., Chicago
C. Lee Cook Mfg. Co., Louisville
Cooper Mfg. Co., Inc., Marshalltown, Iowa
Crandall Packing Co., Palmyra, N. Y.
Crane Packing Co., Chicago, Ill.
Darcoid Co., Inc., New York, N. Y.
Durabla Mfg. Co., New York, N. Y.
Durametallic Corp., Kalamazoo, Mich.
Ferodo & Asbestos, Inc., New Brunswick, N. J.
Flexitallic Gasket Co., Camden, N. J.
Garlock Packing Co., Palmyra, N. Y.
Goetze Gasket & Packing Co., Inc., New York, N. Y.
Goodall Rubber Co., New York, N. Y.
Graton & Knight Co., Worcester, Mass.
Greene, Tweed & Co., N. Y. C.
Home Rubber Co., Trenton, N. J.
Huhn Packing Co., New York, N. Y.
Independent Air Filter Co., Chicago, Ill.
Johns Manville, New York, N. Y.
Manhattan Rubber Mfg. Div., Passaic, N. J.
Metallo Gasket Co., New Brunswick, N. J.
Packing Engineering Corp., Cranford, N. J.
Pioneer Rubber Mills, San Francisco
Quaker City Rubber Co., Phila.
John Reiner & Co., Inc., N. Y. C.
Republic Rubber Co., Youngstown, Ohio
Ryan Metallic Packing Co., Chicago
Thermoid Co., Trenton, N. J.
U. S. Rubber Co., New York, N. Y.
Vellumoid Co., Worcester, Mass.
Victor Mfg. & Gasket Co., Chicago
Jas. Walker & Co., New York, N. Y.
Watson-Stillman Co., Roselle, N. J.
Western Gasket & Mfg. Co., Los Angeles, Calif.

GEARING
Boston Gear Works, Inc., N. Quincy, Mass.
Bridgeport Worm & Gear Mfg. Co., Bridgeport, Conn.
Cleveland Worm & Gear Co., Cleveland, Ohio
Falk Corp., Milwaukee, Wis.
Farrell-Birmingham Co., Ansonia, Conn.
Foote Bros. Gear & Machine Co., Chicago, Ill.
Foote Gear Works, Chicago, Ill.
D. O. James Mfg. Co., Chicago, Ill.
W. A. Jones Foundry & Machine Co., Chicago, Ill.
Link-Belt Co., Chicago, Ill.
Philadelphia Gear Works, Phila.
Pittsburgh Gear & Machine Co., Pittsburgh, Pa.
Twin Disc Clutch Co., Racine, Wis.

GENERATORS & EXCITERS
Allis-Chalmers Mfg. Co., Milwaukee
Crocker-Wheeler Electric Mfg. Co., Ampere, N. J.
Diehl Mfg. Co., Elizabethport, N. J.
Electric Machinery Mfg. Co., Minneapolis, Minn.
Elliott Co., Pittsburgh, Pa.
Fairbanks, Morse & Co., Chicago
Fidelity Electric Co., Lancaster, Pa.
General Electric Co., Schenectady
Ideal Electric & Mfg. Co., Mansfield, Ohio
Terry Steam Turbine Co., Hartford, Conn.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GOVERNORS
A. W. Cash Co., Decatur, Ill.
Gardner-Denver Co., Quincy, Ill.
Handy Governor Corp., Detroit
Jarecki Mfg. Co., Erie, Pa.
Massey Machine Co., Watertown, N. Y.
Pickering Governor Co., Portland, Conn.
Pierce Governor Co., Anderson, Ind.
United American Bosch Corp., Springfield, Mass.
Woodward Governor Co., Rockford, Ill.

GREASE
(See Oil—Fuel and Lubricants)

HEAT EXCHANGERS
Alco Products, Inc., New York, N. Y.
Andale Co., Philadelphia, Pa.
Babcock & Wilcox Co., N. Y. C.
Carbondale Machine Corp., Harrison, N. J.
Croll-Reynolds Engineering Co., Inc., New York, N. Y.
Combustion Engrg. Co., Inc., N. Y. C.
Davis Engineering Corp., Elizabeth, N. J.
Edge Moor Iron Co., N. Y. C.
Elgin Softener Corp., Elgin, Ill.
Foster Wheeler Corp., N. Y. C.
G & O Mfg. Co., New Haven, Conn.
Griscom-Russell Co., New York, N. Y.
Harrison Radiator Div., Lockport, N. Y.
Heat Exchanger Co., Grove City, Pa.
Lilie-Hoffman Cooling Towers, Inc., St. Louis, Mo.
The Marley Co., St. Louis, Mo.
J. F. Pritchard & Co., Kansas City, Mo.
Schubert-Christy Corp., Affton, Mo.
Schutte & Koerting Co., Philadelphia
The Sims Co., Erie, Pa.
Henry Vogt Machine Co., Louisville
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
C. H. Wheeler Mfg. Co., Philadelphia
Worthington Pump & Machinery Co., Harrison, N. J.

HEATERS, OIL
(See Coolers, Oil)

HOSE, FLEXIBLE METALLIC
American Brass Co., Waterbury, Conn.
Atlantic Metal Hose Co., Inc., New York, N. Y.
Chicago Tubing & Braiding Co., Chicago, Ill.
Flex-O-Tube Co., Detroit, Mich.
Pennsylvania Flexible Metallic Tubing Co., Philadelphia, Pa.
Seamless Corp., Long Island City, N. Y.
Titeflex Metal Hose Co., Newark, N. J.
United Metal Hose Co., Inc., N. Y. C.

HOSE, OIL-PROOF RUBBER
B. F. Goodrich Co., Akron, Ohio
Boston Woven Hose & Rubber Co., Boston, Mass.
Goodyear Tire & Rubber Co., Akron
Manhattan Rubber Mfg. Div., Passaic, N. J.
Thermoid Co., Trenton, N. J.
U. S. Rubber Co., New York, N. Y.

INDICATORS, SPEED, ETC.
Bacharach Industrial Instrument Co., Pittsburgh, Pa.
James G. Biddle Co., Philadelphia
Bristol Co., Waterbury, Conn.
Cutler-Hammer Inc., Milwaukee
Leeds & Northrup Co., Philadelphia
George Scherr Co., Inc., N. Y. C.
C. J. Tagliabue Mfg. Co., Brooklyn
Trill Indicator Co., Corry, Pa.

INDICATORS, SIGHT-FLOW
Lunkenheimer Co., Cincinnati, Ohio
Wm. W. Nugent & Co., Inc., Chicago
Schutte & Koerting Co., Phila.

INDICATORS, FREQUENCY
Leeds & Northrup Co., Philadelphia
Roller-Smith Co., New York, N. Y.

INJECTION SYSTEMS, FUEL
Ex-Cell-O Aircraft & Tool Corp., Detroit, Mich.
Murphy Diesel Co., Ltd., Milwaukee
Nicholas Fodor, New York, N. Y.
Timken Roller Bearing Co., Canton, Ohio
United American Bosch Corp., Springfield, Mass.
Viking Pump Co., Cedar Falls, Iowa

INSTRUMENTS, ELECTRIC
James G. Biddle Co., Philadelphia
Bristol Co., Waterbury, Conn.
Duncan Electric Mfg. Co., Lafayette, Ind.
Esterline-Angus Co., Indianapolis
General Electric Co., Schenectady
Leonard Electric Mfg. Co., Cleveland
Norton Electrical Instrument Co., Manchester, Conn.
Roller-Smith Co., New York, N. Y.
R. E. S. Swann & Co., Hanover, Pa.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Weston Electrical Instrument Corp., Newark, N. J.

INSTRUMENT PANELS, ENGINE
Viking Instruments, Inc., N. Y. C.

INSTRUMENT, TESTING
General Electric Co., Schenectady
Leeds & Northrup Co., Philadelphia
C. J. Tagliabue Mfg. Co., Brooklyn
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Weston Electrical Instrument Corp., Newark, N. J.

INSULATION MATERIALS
Armstrong Cork Products Co., Lancaster, Pa.
Philip Carey Co., Lockland, Cincinnati, Ohio
Eagle Picher Lead Co., Joplin, Mo.
Johns Manville, New York, N. Y.
Keasby & Mattison Co., Ambler, Pa.
Mikolite Co., Kansas City, Mo.
Owens-Illinois Glass Co., Toledo, Ohio

ISOLATION—CORK, FELT, RUBBER, SPRING
Armstrong Cork Products Co., Lancaster, Pa.
American Steel & Wire Co., N. Y. C.
Keldur Corp., New York, N. Y.
Korfund Co., Inc., Long Island City, N. Y.
Manhattan Rubber Mfg. Div., Passaic, N. J.
Mundet Cork Corp., New York, N. Y.
United Cork Cos., Lyndhurst, N. Y.
U. S. Gypsum Co., Chicago, Ill.
U. S. Metal Hose Co., Inc., N. Y. C.
Vibration Elimination Co., Long Island City, N. Y.

JOINTS, FLEXIBLE
Foster Wheeler Corp., N. Y. C.
Jarecki Mfg. Co., Erie, Pa.
Moran Flexible Joint Co., Louisville
National Valve & Equipment Co., Pittsburgh, Pa.
Pittsburgh Valve Foundry & Construction Co., Pittsburgh, Pa.
United Metal Hose Co., Inc., N. Y. C.

LINERS, CYLINDER
Farrell-Birmingham Co., Ansonia, Conn.
Hunt-Spiller Mfg. Co., S. Boston
Sun Shipbuilding & Drydock Co., Chester, Pa.
Thompson Products, Inc., Cleveland

LUBRICATORS
Alemite Corp., Chicago, Ill.
S. F. Bowser & Co., Inc., Fort Wayne, Ind.
Detroit Lubricator Co., Detroit
Greene, Tweed & Co., N. Y. C.
Ideal Lubricator Co., Philadelphia
J. E. Lonergan Co., Philadelphia
Lunkenheimer Co., Cincinnati, Ohio
Madison-Kipp Lubricator Co., Madison, Wis.
Manzel Bros. Co., Buffalo, N. Y.
Penberthy Injector Co., Detroit
Quimby Pump Co., Newark, N. J.
United American Bosch Corp., Springfield, Mass.
Victor Lubricator Co., Chicago

MANIFOLDS, SILENCING
Burgess Battery Co., Madison, Wis.
Detroit Gasket & Mfg. Co., Detroit

MANOMETERS
American Blower Corp., Detroit
American Instrument Co., Washington, D. C.
Bacharach Industrial Instrument Co., Pittsburgh, Pa.
Bailey Meter Co., Cleveland, Ohio
Defender Automatic Regulator Co., St. Louis, Mo.
Ellison Draft Gage Co., Chicago
Meriam Co., Cleveland, Ohio
Republic Flow Meters Co., Chicago
Schutte & Koerting Co., Phila.
Simplex Valve & Meter Co., Phila.

METERS, WATER OR OIL
American Liquid Meter Co., Alhambra, Calif.
Brown Instrument Co., Philadelphia
S. F. Bowser & Co., Inc., Fort Wayne, Ind.
Buffalo Meter Co., Buffalo, N. Y.
Builders Iron Foundry, Providence, R. I.
Elgin Softener Corp., Elgin, Ill.
Foxboro Co., Foxboro, Mass.
National Meter Co., Brooklyn, N. Y.
Neptune Meter Co., New York, N. Y.
Pittsburgh Equitable Meter Co., Pittsburgh, Pa.
Republic Flow Meters Co., Chicago
Simplex Valve & Meter Co., Phila.
Visco Meter Corp., Buffalo, N. Y.
Worthington Pump & Machinery Corp., Harrison, N. J.
Yarnall-Waring Co., Philadelphia

METERS, TEMPERATURE
Automatic Temperature Control Co., Philadelphia, Pa.
Bailey Meter Co., Cleveland, Ohio
Bristol Co., Waterbury, Conn.
Electric Auto-Lite Co., Moto Meter Gauge & Equipt. Div., N. Y. C.
Brown Instrument Co., Philadelphia
Builders Iron Foundry, Providence
A. W. Cash Co., Decatur, Ill.
Esterline-Angus Co., Indianapolis
Foxboro Co., Foxboro, Mass.
Illinois Testing Labs., Inc., Chicago
Leeds & Northrup Co., Philadelphia
Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
National Meter Co., Brooklyn, N. Y.
Taylor Instrument Cos., Rochester, N. Y.
Thwing-Albert Instrument Co., Philadelphia, Pa.
U. S. Gauge Co., New York, N. Y.
Viscosity Engineering Co., N. Y. C.
Weston Electrical Instrument Corp., Newark, N. J.

MUFFLERS, INTAKE & EXHAUST
Burgess Battery Co., Madison, Wis
Engineering Specialty Co., Inc., New York, N. Y.
Foster Wheeler Corp., N. Y. C.
Maxim Silencer Co., Hartford, Conn.

OIL, FUEL & LUBRICATING
Acheson Colloids Corp., Port Huron, Mich. (Colloidal graphite)
Borne-Scrymser Co., New York, N. Y.
Cities Service Co., New York, N. Y.
Continental Oil Co., Ponca City, Okla
Adam Cook's Sons Co., Linden, N. J.
Deep Rock Oil Corp., Chicago, Ill.
Diesel Oil Co., Corpus Christi, Tex.
Jos. Dixon Crucible Co., Jersey City, N. J. (Graphite)
Gulf Refining Co., Pittsburgh, Pa.
E. F. Houghton & Co., Phila.
Keystone Lubricating Co., Phila.
The Lubal Co., Columbus, Ohio (Lubricating concentrate in fuel)
Lubriplate Corp., New York, N. Y.
Marathon Oil Co., Tulsa, Okla.
Nassau Laboratories, New York, N. Y. (Colloidal graphite)
National Refining Co., Cleveland
Macmillan Petroleum Corp., Los Angeles, Calif.
Pennzoil Co., Oil City, Pa.
Phillips Petroleum Co., Bartlesville, Okla.
Pure Oil Co., Chicago, Ill.
Pyroil Co., La Crosse, Wis. (Concentrate)
Shell Petroleum Corp., St. Louis
Sinclair Refining Co., N. Y. C.
Socony-Vacuum Corp., N. Y. C.
Standard Oil Co. (Indiana), Chicago
Standard Oil Co. (Calif.), Los Angeles
Sun Oil Co., Philadelphia, Pa.
Texas Petroleum Products Co., San Antonio, Tex.
The Texas Co., New York, N. Y.
Tide Water Oil Co., New York, N. Y.
Viscosity Oil Co., Chicago, Ill.
Waverly Oil Works, Pittsburgh, Pa.

OIL PURIFICATION SYSTEMS
Alco Products, Inc., New York, N. Y.
De Laval Separator Co., N. Y. C.
De Laval Steam Turbine Co., East Trenton, N. J.
De La Vergne Engine Co., Phila.
Goulds Pumps, Inc., Seneca Falls, N. Y.
Hilliard Corp., Elmira, N. Y.
Motor Improvements, Inc., Newark, N. J.
Wm. W. Nugent & Co., Inc., Chicago
Sharples Specialty Co., Phila.
Skinner Purifiers, Inc., Detroit

OIL RECLAMATION SYSTEMS
Goulds Pumps, Inc., Seneca Falls, N. Y.
Wm. W. Nugent Co., Inc., Chicago
Skinner Purifiers, Inc., Detroit
Youngstown Steel Car Corp., Niles, Ohio

PACKING
(See Gaskets and Packing)

PIPE FITTINGS AND PIPE
Bonney Forge & Tool Works, Allentown, Pa.
Boston Woven Hose & Rubber Co., Boston, Mass.
A. M. Byers Co., Pittsburgh, Pa.
Chase Brass & Copper Co., Waterbury, Conn.
Crane Co., Chicago, Ill.
Grinnell Co., Providence, R. I.
Homestead Valve & Mfg. Co., Coraopolis, Pa.
Jarecki Mfg. Co., Erie, Pa.
Jefferson Union Co., New York, N. Y.
Jones & Laughlin Steel Corp., Pittsburgh, Pa.
E. F. Keating Pipe Bending & Supply Co., New York, N. Y.
Lunkenheimer Co., Cincinnati, Ohio
Maryland Pipe & Steel Corp., Baltimore, Md.
Midwest Piping & Supply Co., St. Louis, Mo.
National Valve & Mfg. Co., Pittsburgh, Pa.
Wm. W. Nugent & Co., Inc., Chicago
Pennsylvania Forge Co., Phila.
Pittsburgh Piping & Equipt. Co., Pittsburgh, Pa.
Pittsburgh Steel Co., Pittsburgh
Reading Iron Co., Reading, Pa.
Republic Steel Corp., Youngstown, O.
Rockwood Sprinkler Co., Worcester, Mass.
John Simmons Co., Long Island City, N. Y.
Stockham Pipe & Fitting Co., Birmingham, Ala.
Taylor Forge & Pipe Works, Chicago
Tube Turns, Inc., Louisville, Ky.
United Metal Hose Co., N. Y. C.
Henry Vogt Machine Co., Louisville
Watson-Stillman Co., Roselle, N. J.
Weatherhead Co., Cleveland, Ohio

PISTONS
Arrow Head Steel Products Co., Minneapolis, Minn.
Delco-Remy Corp., Anderson, Ind.
De Luxe Products Co., LaPorte, Ind.
Ray Day Piston Corp., Detroit
Thompson Products, Inc., Cleveland

PISTON RINGS
American Hammered Piston Ring Div., Baltimore, Md.
C. Lee Cook Mfg. Co., Inc., Louisville, Ky.
Double Seal Ring Corp., N. Y. C.
Perfect Circle Co., Hagerstown, Ind.
Sealed Power Corp., Muskegon, Mich.
Skinner Chuck Co., New Britain, Conn.
Thompson Products, Inc., Cleveland
A. P. Ward, Inc., Cincinnati, Ohio

PUMPS
Allis-Chalmers Mfg. Co., Milwaukee
Byron Jackson Co., Berkeley, Calif.
Blackmer Rotary Pump Co., Grand Rapids, Mich.
Dayton-Dowd Pump Co., Quincy, Ill.
Dean-Hill Pump Co., Anderson, Ind.
Deming Co., Salem, Ohio
Evans Appliance Co., Detroit
Ex-Cell-O Aircraft & Tool Corp., Detroit, Mich.
Fairbanks, Morse & Co., Chicago
Foster Wheeler Corp., N. Y. C.
Gardner-Denver Co., Quincy, Ill.
Goulds Pumps, Inc., Seneca Falls, N. Y.
Ingersoll-Rand Co., New York, N. Y.
Kinney Mfg. Co., Boston, Mass.
Manzel Bros. Co., Buffalo, N. Y.
Nash Engineering Co., South Norwalk, Conn.
Northern Pump Co., Minneapolis
Wm. W. Nugent & Co., Inc., Chicago
Quincy Compressor Co., Quincy, Ill.
Geo. D. Roper & Co., Rockford, Ill.
Roots-Connersville Blower Corp., Connersville, Ind.
Schutte & Koerting Co., Phila.
Tuthill Pump Co., Chicago, Ill.
Viking Pump Co., Cedar Falls, Iowa
Warren Steam Pump Co., Warren, Mass.
Westco Pump Co., Davenport, Iowa
Worthington Pump & Machinery Corp. Harrison, N. J.

PYROMETERS
Bailey Meter Co., Cleveland, Ohio
Bristol Co., Waterbury, Conn.
Brown Instrument Co., Philadelphia
Defender Automatic Regulator Co., St. Louis., Mo.
Foxboro Co., Foxboro, Mass.
Ill. Testing Labs., Inc., Chicago
Leeds & Northrup Co., Philadelphia
Mishawaka Industrial Instrument Mfg. Lab., Mishawaka, Ind.
C. J. Tagliabue Mfg. Co., Brooklyn
Taylor Instrument Cos., Rochester, N. Y.
Thermal Control Devices, Inc., Chicago, Ill.
Thwing-Albert Instrument Co., Phila.

RADIATORS
American Radiator Co., N. Y. C.
Perfex Radiator Co., Milwaukee
Rome-Turney Radiator Co., Rome, N. Y.
Young Radiator Co., Racine, Wis.

RECEIVERS, AIR
Ingersoll-Rand Co., New York, N. Y.

RECORDERS
Bailey Meter Co., Cleveland, Ohio
Bristol Co., Waterbury, Conn.
Foxboro Co., Foxboro, Mass.
Leeds & Northrup Co., Philadelphia
Electric Auto-Lite Co., Moto Meter Gauge & Equipt. Div., N. Y. C.
U. S. Gauge Co., New York, N. Y.

REGULATORS, CURRENT AND VOLTAGE
Allis-Chalmers Mfg. Co., Milwaukee
Bromfield Mfg. Co., Inc., Boston
Burlington Instrument Corp., Burlington, Iowa
General Electric Co., Schenectady
Simplex Corp., Burlington, Iowa
Ward Leonard Electric Co., Mt. Vernon, N. Y.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

REPAIRS
Fairbanks Morse & Co., Chicago
Diesel Engine Service, N. Y. C.
Diesel Plant Specialties Co., Chicago
Frazier Wright Co., Ltd., Los Angeles, Calif.
Washington Iron Works, Sherman, Texas

SAFETY CONTROL, ENGINE
Thomas A. Edison, Inc., West Orange, N. J.
Fulton Sylphon Co., Knoxville, Tenn.
Ill. Testing Labs., Inc., Chicago
Viking Instruments, Inc., N. Y. C.

SCALE RETARDERS, JACKET WATER
Artic Chemical & Combustion Engrg. Corp., Brooklyn, N. Y.
W. H. & L. D. Betz, Philadelphia
Dearborn Chemical Co., Chicago
Feedwaters, Inc., New York, N. Y.
Rathbun Co., Inc., El Paso, Tex.
National Aluminate Co., Chicago

SCHOOLS, DIESEL ENGINEERING
L. L. Adcox Trade School, Portland, Ore.
Delehanty Institute Diesel School, New York, N. Y.
Diesel Power Engineering Schools, San Francisco, Calif.
Empire Diesel Schools, Brooklyn, N. Y.
Hemphill Diesel Engineering Schools: Boston, Mass., Long Island City, N. Y., Detroit, Mich., Chicago, Ill., Memphis, Tenn., Los Angeles, Calif., Seattle, Wash., Vancouver, B. C.
Jourden Diesel Schools, Inc., Philadelphia, Pa.
Midwest Diesel Institute, Alton, Ill., and Elyria, Ohio
New Jersey Diesel School, Inc., Newark, N. J.
New York Diesel Institution, Inc., Albany, N. Y., Newark, N. J.
Dr. O. F. Schoek School of Diesel Engrg., Alton, Ill.
U. S. Diesel School, Boston, Mass.

SEPARATORS, SEDIMENT
Cochrane Corp., Philadelphia, Pa.
Crane Co., Chicago, Ill.
Sharples Specialty Co., Phila.
Strong, Carlisle & Hammond Co., Cleveland, Ohio
Swartwout Co., Cleveland, Ohio

SHIMS
Keystone Gasket Mfg. Co., Phila.
Laminated Shim Co., Long Island City, N. Y.
National Motor Bearing Co., Inc., Oakland, Calif.
Victor Mfg. & Gasket Co., Chicago

SILENCERS
Burgess Battery Co., Madison, Wis.
Maxim Silencer Co., Hartford, Conn.
Staynew Filter Corp., Rochester, N. Y.

SOFTENERS, WATER
Cochrane Corp., Philadelphia, Pa.
Crane Co., Chicago, Ill.
Dearborn Chemical Co., Chicago
Elgin Softener Co., Elgin, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
Hungerford & Terry, Inc., Clayton, N. J.
International Filter Co., Chicago
National Aluminate Corp., Chicago
Permutit Co., New York, N. Y.
Wm. B. Scaife & Sons, Oakmont, Pa.
Zeolite Chemical Co., N. Y. C.

SPEED REDUCERS AND INCREASERS
(See also Gearing)
Boston Gear Works, Inc., N. Quincy, Mass.
Link-Belt Co., Chicago, Ill.
Philadelphia Gear Works, Phila.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

SPRAY PONDS
Binks Mfg. Co., Chicago, Ill.
Edwin Burhorn Co., Hoboken, N. J.
Cooling Tower Co., Inc., N. Y. C.
Marley Co., Kansas City, Mo.
Monarch Mfg. Works, Philadelphia
Yarnall-Waring Co., Philadelphia

STARTING UNITS
Allen-Bradley Co., Milwaukee, Wis.
Atlas-Imperial Diesel Engine Co., Oakland, Calif.
Bolinders Co., Inc., New York, N. Y.
Cooper-Bessemer Corp., Mt. Vernon, Ohio
Cutler-Hammer, Inc., Milwaukee
Delco-Remy Corp., Anderson, Ind.
Fairbanks, Morse & Co., Chicago
Gardner-Denver Co., Quincy, Ill.
General Electric Co., Schenectady
Hill Diesel Engine Co., Lansing, Mich.
Ingersoll-Rand Co., New York, N. Y.
Novo Engine Co., Lansing, Mich.
Quincy Compressor Co., Quincy, Ill.
Sullivan Machinery Co., Chicago
Waukesha Motor Co., Waukesha, Wis.
Worthington Pump & Machinery Corp., Harrison, N. J.

STEEL—GRATING, LADDERS
Blaw-Knox Co., Pittsburgh, Pa.
Central Iron & Steel Co., Harrisburg, Pa.
Hendricks Mfg. Co., Carbondale, Pa.
Illinois Steel Co., Chicago, Ill.
Irving Iron Works Co., L. I. City, N. Y.
Kerlow Steel Flooring Co., Jersey City, N. J.

STEEL, STRUCTURAL
Bethlehem Steel Co., Bethlehem, Pa.
Carnegie Steel Co., Pittsburgh, Pa.
Jones & Laughlin Steel Corp., Pittsburgh, Pa.
Republic Steel Corp., Youngstown, O.

STRAINERS
Andale Co., Philadelphia, Pa.
Blackburn-Smith Corp., Hoboken, N. J.
Edward Valve & Mfg. Co., East Chicago, Ind.
Elliott Co., Pittsburgh, Pa.
Jas. P. Marsh Corp., Chicago, Ill.
Sarco Co., Inc., New York, N. Y.
Strong, Carlisle & Hammond Co., Cleveland, Ohio
Watts Regulator Co., Lawrence, Mass.

SWITCHES AND SWITCHBOARDS
Allis-Chalmers Mfg. Co., Milwaukee
Bristol Co., Waterbury, Conn.
Bromfield Mfg. Co., Inc., Boston
Commonwealth Electric Co., St. Paul, Minn.
Delco-Remy Corp., Anderson, Ind.
General Electric Co., Schenectady
Ideal Electric & Mfg. Co., Mansfield, Ohio
Lexington Elec. Products Co., Inc., New York, N. Y.
H. Listenwarter Co., Chicago, Ill.
Roller-Smith Co., New York, N. Y.
Sundh Electric Co., Cleveland, O.
Square D Co., Detroit, Mich.
Standard Swbd. Co., Brooklyn, N. Y.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Wm. Wurdack Electric Mfg. Co., St. Louis, Mo.
Woolfe & Mann Mfg. Co., Baltimore

TACHOMETERS, ELECTRIC
General Electric Co., Schenectady
Ill. Testing Labs., Inc., Chicago
Viking Instruments, Inc., N. Y. C.
Weston Electrical Instrument Corp., Newark, N. J.

TANKS, STORAGE
Alberger Heater Co., Buffalo, N. Y.
S. F. Bowser & Co., Inc., Fort Wayne, Ind.
W. E. Caldwell Co., Inc., Louisville
Connery Construction Co., Phila.
Graver Tank & Mfg. Co., East Chicago, Ind.
Hedges-Walsh-Weidner Co., Chattanooga, Tenn.
Littleford Tube Co., Pittsburgh, Pa.
National Tube Co., Pittsburgh, Pa.
Mecklenberg Iron Works, Charlotte, N. C.
Wm. W. Nugent & Co., Inc., Chicago
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Wm. B. Scaife & Sons Co., Oakmonte, Pa.
Sheet Metal & Conveyor Co., Chicago
Tulsa Boiler & Machinery Co., Tulsa, Okla.

THERMOCOUPLES
Bristol Co., Waterbury, Conn.
Brown Instrument Co., Philadelphia
Foxboro Co., Foxboro, Mass.
Illinois Testing Labs., Inc., Chicago
Leeds & Northrup Co., Philadelphia
C. J. Tagliabue Mfg. Co., Brooklyn

THERMOMETERS
American Temperature Indicating Co., Toledo, Ohio
Bailey Meter Co., Cleveland, Ohio
Bristol Co., Waterbury, Conn.
Brown Instrument Co., Philadelphia
Consolidated Ashcroft Hancock Co., Inc., Bridgeport, Conn.
Defender Automatic Regulator Co., St. Louis, Mo.
Diesel Plant Specialties Co., Chicago
Charles Englehart, Inc., Newark, N. J.
Foxboro Co., Foxboro, Mass.
King-Seeley Corp., Ann Arbor, Mich.
Leeds & Northrup Co., Philadelphia
Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
Ill. Testing Labs., Inc., Chicago
Precision Thermometer & Instrument Co., Philadelphia, Pa.
C. J. Tagliabue Mfg. Co., Brooklyn
Taylor Inst. Co's., Rochester, N. Y.
Uehling Instrument Co., Patterson, N. J.
Viking Instruments, Inc., N. Y. C.

TRANSMISSIONS
(See Gearing, Drives, Clutches)

VALVES
Ashton Valve Co., Cambridge, Mass.
Atlas Valve Co., Newark, N. J.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Collar Valve Corp., Berkeley, Calif.
Crane Co., Chicago, Ill.
Crosby Steam Gage & Valve Co., Boston, Mass.
Davis Regulator Co., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Edward Valve & Mfg. Co., East Chicago, Ind.
Everlasting Valve Co., Jersey City, N. J.
Fairbanks Co., New York, N. Y.
Homestead Valve & Mfg. Co., Coraopolis, Pa.
Hudson Brass Works, Brooklyn, N. Y.
Jenkins Bros., New York, N. Y.
Leslie Co., Lyndhurst, N. J.
L. E. Lonergan & Co., Philadelphia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Lunkenheimer Co., Cincinnati, Ohio
Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
Wm. W. Nugent & Co., Inc., Chicago
Pittsburgh Equitable Meter Co., Pittsburgh, Pa.
Pittsburgh Piping & Equipt. Co., Pittsburgh, Pa.
Wm. Powell Co., Cincinnati, Ohio
Reading-Pratt & Cady Co., Inc., Bridgeport, Conn.
Ross Valve Co., Troy, N. Y.
John Simmons Co., Long Island City, N. Y.
Swartwout Co., Cleveland, Ohio
Sweet & Doyle, Troy, N. Y.
United American Bosch Corp., Springfield, Mass. (Fuel Spray)
Henry Vogt Machine Co., Louisville
J. H. H. Voss, Inc., New York, N. Y.
Walworth Co., New York, N. Y.
Watson-Stillman Co., Roselle, N. Y.
D. T. Williams Valve Co., Cincinnati, Ohio
Yarnall-Waring Co., Philadelphia

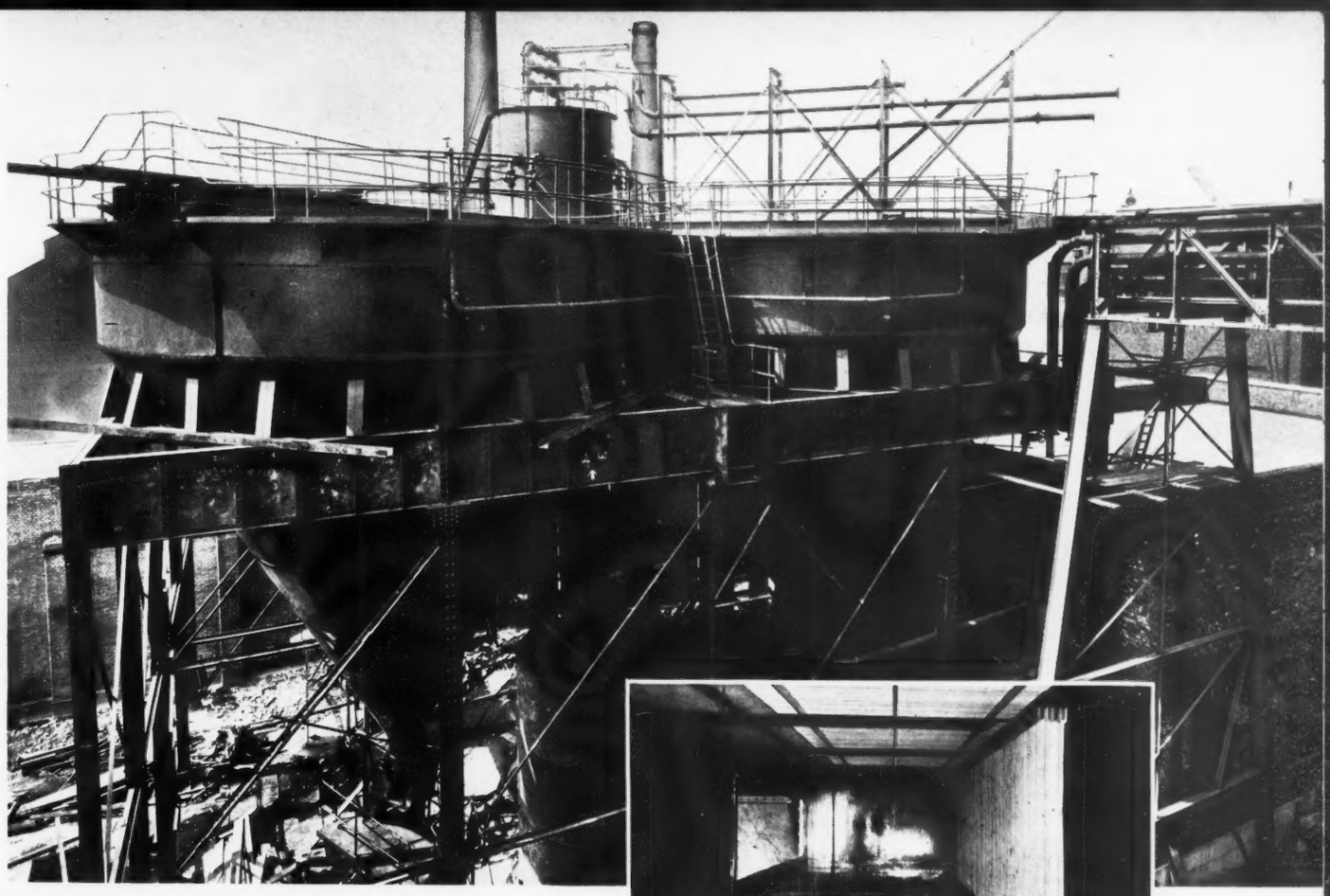
VALVE REGRINDING EQUIPMENT
Hutton & Jenks, Bancroft, Iowa
Leavitt Machine Co., Orange, Mass.

VIBROMETERS
James G. Biddle Co., Philadelphia
Electrocon Corp., New York, N. Y.
L. S. Starrett Co., Athol, Mass.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

CONSULTANTS

Oliver F. Allen, 117 Liberty St., New York, N. Y.
J. W. Anderson, 135 Broadway, Rockville Center, Long Island, N. Y.
Bahnsen Engineering Co., 240 120th St., Rockaway Park, Long Island, N. Y.
Ballinger Co., 105 12th St., Philadelphia, Pa., 233 Broadway, New York, N. Y.
M. D. Bell, 806 Metropolitan Life Bldg., Minneapolis, Minn.
Joseph Breslove, Oliver Bldg., Pittsburgh, Pa.
Bryan & Sigmon Engineering Co., Inc., Newton Falls, Ohio
Buell & Winter Engineering Co., Sioux City, Iowa
Burns & McDonnell Engineering Co., Kansas City, Cincinnati, Miami
S. W. Calhoun, Ashville, N. C.
Robert Cramer & Sons, 647 W. Virginia St., Milwaukee, Wis.
H. L. Cory Engineering Co., Omaha, Neb.
D. H. Dashiel, Insurance Bldg., San Antonio, Tex.
Howard E. Degler, 3500 Greenway, Austin, Tex.
F. E. Dobbs, Wentworth Institute, Boston, Mass.
Dowell, Lockwood & Andrews, 512 Esperson Bldg., Houston, Tex.
David V. Fennessy, 1108 Bassett Tower, El Paso, Tex.
Isaac Fidler, 217 Willowbrook St., High Point, N. C.
Foster & Wahlberg, Medical Arts Bldg., Duluth, Minn.
T. M. Francis, Brown-Marx Bldg., Birmingham, Ala.
W. A. Fuller Co., St. Louis, Mo.
W. S. Heer Engineering Co., 1205 Times Star Bldg., Cincinnati, Ohio
W. R. Holway Co., Oklahoma City, Okla.
Myron S. Huckle, 89 Brighton Ave., Boston, Mass.
Samuel R. Hunter, 608 S. Dearborn St., Chicago, Ill.
Edgar J. Kates, 415 Lexington Ave., New York, N. Y.
Peter F. Loftus, Pittsburgh, Pa.
W. B. Rollins & Co., 339 Railway Exchange Bldg., Kansas City, Mo.
Carl J. Simon, Van Wert, Ohio
Young & Stanley, Inc., 211 Iowa Ave., Muscatine, Iowa

Listings are as complete and accurate as available information permits, but Power assumes no responsibility for errors or omissions.



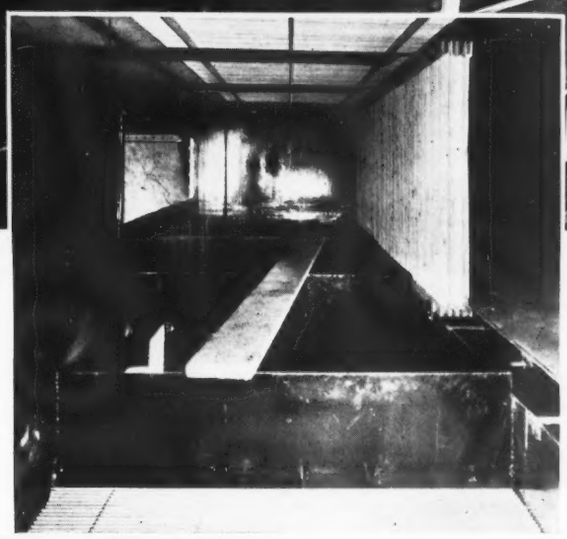


Fig. 1 (above)—Settling tanks from which sludge is removed. Fig. 2 (at right)—Rain chamber, showing wood filler at bottom and moisture eliminators at right

FULHAM WASHES FLUE GAS

By D. W. Rudorff

Dipl. Engr.

TO KEEP the new 300,000-kw., 625-lb., 850-deg. Fulham power plant from adding to London's smoke problem, permission for construction was granted by the authorities only under the condition that highly efficient flue-gas-washing equipment would be installed to suppress the discharge of both flue dust and sulphurous fumes from its chimneys. Considering the fact that this plant when completed will consume daily 2,200 tons of coal containing from 0.75 to 1.5% sulphur, thus burning up to 33 tons of sulphur per day—and this in the midst of a thickly populated metropolitan quarter of London—sulphur removal from the stack discharge was indeed necessary. It was also decreed that no waste products resulting from the washing process should be discharged into the river Thames from which the plant's cooling water supply is drawn. Consequently a flue-gas-washing process with a closed liquor circuit had to be evolved. Research was undertaken on a working scale in a pilot plant specially designed and constructed by James Howden & Co. (Land) Ltd. in collaboration with Imperial Chemical Industries Ltd. The process finally developed is known as the Howden - ICI system of gas scrubbing; this system is now also in use in the recently constructed Tir John power plant at Swansea.

The flue-gas-washing plant installed is capable of reducing the sulphur compounds in the flue gas to 0.02 grains per cu.ft., and its dust content to 0.08 grains per cu.ft. (at atmospheric pressure and 32 F.). It consists of a scrubber system in which the intimate contact between washing liquid and flue gas is obtained by a combination of rain and surface-film action. To achieve a complete, or at least a substantially complete, absorption and neutralization of the SO_2 and other acid constituents, milk of lime is added to the washing water. This lime combines with CO_2 absorbed from the flue gas to produce both chalk (which is insoluble) and calcium carbonate (which is soluble). This latter constitutes the active absorbing and neutralizing agent, and fresh amounts are continually formed from the chalk as the absorption and neutralization of the acid constituents proceeds. To keep up the supply of calcium bicarbonate and to prevent the recirculating liquor from becoming acid, fresh milk of lime is fed into the system at a rate proportional to the acid absorption. Under such conditions, the pH value of the washing liquor is maintained at 6.7 - 6.8 at the scrubber inlet, and at 6.4 - 6.6 at the liquor exit of the scrubber.

SO_2 and SO_3 contained in the flue

GOOD NEWS

Good news travels fast, particularly within an industry when a company installs new equipment which gives unusually satisfactory results. Such news quickly reaches other companies in the industry.

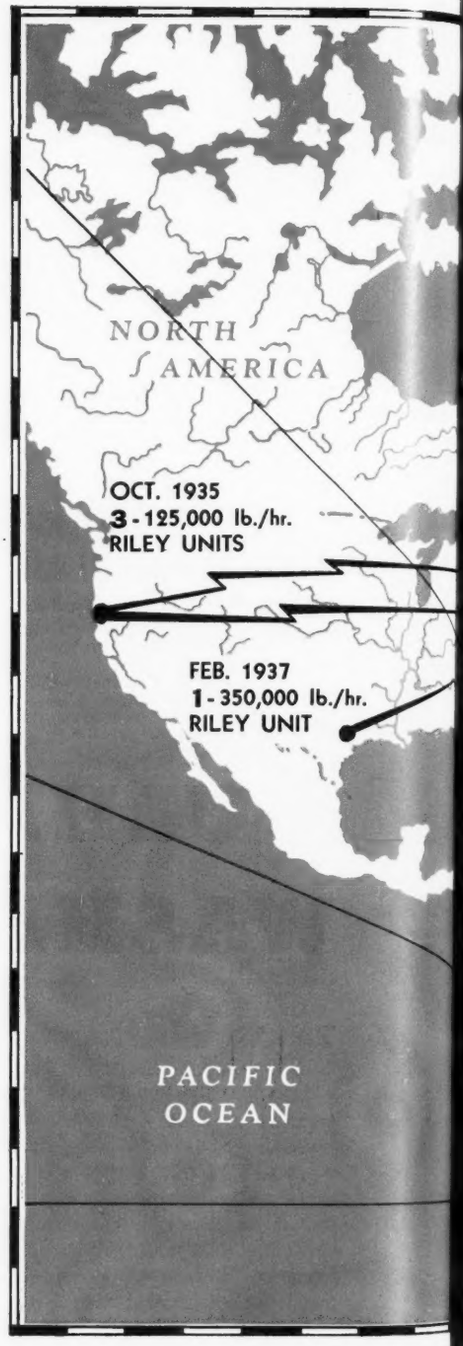
In 1934 Riley placed into operation a modern steam generating unit at the plant of a large eastern oil refinery. News of the outstanding performance obtained at this installation soon reached other oil companies . . . thorough investigations were made.

As a result Riley equipment has been selected for the recent outstanding oil refinery boiler installations. October 1935 . . . Standard Oil Co. of California for Richmond, Cal.; August 1936 . . . Bahrein Refinery for Bahrein Islands in the Persian Gulf; December 1936 . . . a repeat order for the large eastern refinery; February 1937 . . . Humble Oil & Refining Co. for Baytown, Texas.

What has happened in the oil industry is happening throughout all industry, carrying sales of Riley Steam Generating Equipment many times in excess of all previous sales records.

The entire satisfaction being obtained from recent Riley installations is further proven by the fact that in 1936 repeat orders represented 61.4% of total sales.

Be sure to consult Riley when considering the installation of steam generating or fuel burning equipment.



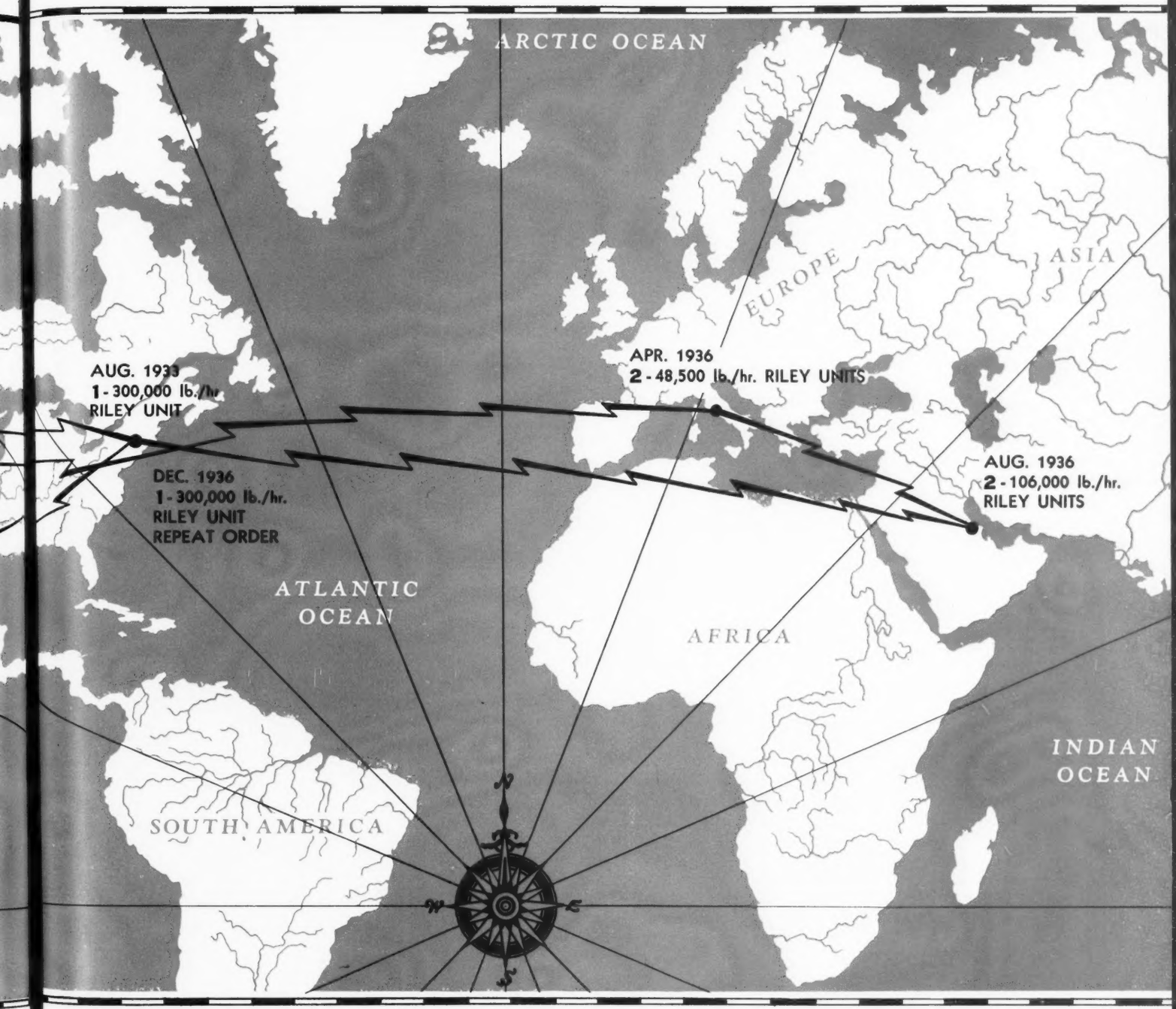
RILEY
STOKER CORPORATION
WORCESTER, MASSACHUSETTS

COMPLETE STEAM GENERATING UNITS

BOILERS - SUPERHEATERS - AIR HEATERS - ECONOMIZERS - PULVERIZERS - BURNERS - STOKERS - WATER-COOLED FURNACES - STEEL CLAD SETTINGS

BOSTON NEW YORK PHILADELPHIA PITTSBURGH BUFFALO CLEVELAND
DETROIT TACOMA BALTIMORE ST. LOUIS CINCINNATI HOUSTON
CHICAGO ST. PAUL KANSAS CITY MILWAUKEE LOS ANGELES ATLANTA

TRAVELS FAST



RILEY'S PROGRESS IN THE OIL INDUSTRY

AUGUST - 1933 Large Eastern Oil Refinery, 1-300,000 lbs./hr., 650 lbs., 740°F. steam

OCTOBER - 1935 Standard Oil Co. of Calif., Richmond, Calif., 3-125,000 lbs./hr., 900 lbs., 760°F. steam

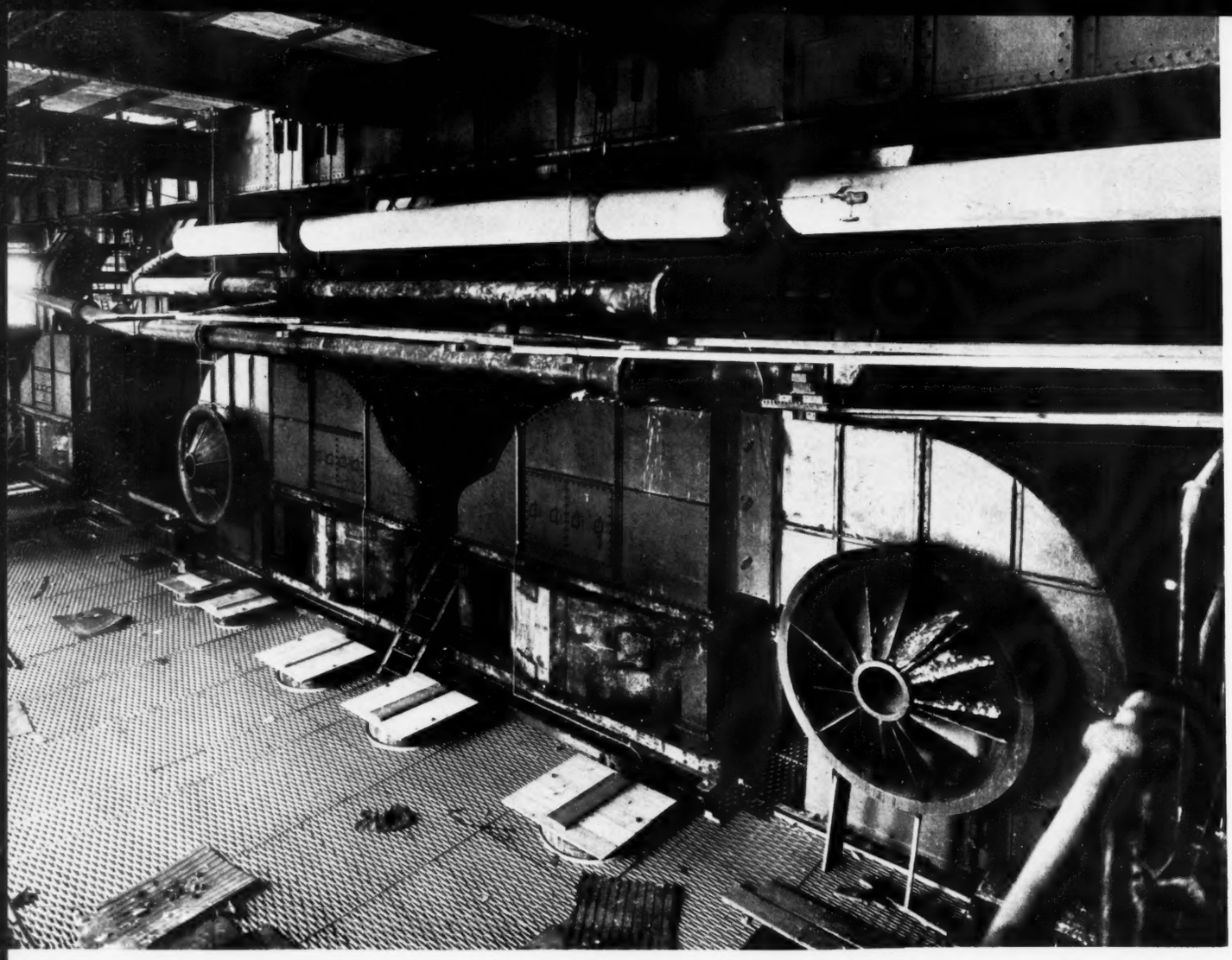
APRIL - 1936 Raffineria Di Napoli, Naples, Italy, Socony Vacuum Oil Co., 2-48,500 lbs./hr., 752 lbs., 712°F. steam, Riley Steam Generating Units

AUGUST - 1936 Bahrein Refinery, Bahrein Islands, Persian Gulf, Standard Oil Co. of California, 2-106,000 lbs./hr., 600 lbs., 750°F. steam, Riley Steam Generating Units

DECEMBER - 1936 Repeat order, Large Eastern Oil Refinery, 1-300,000 lbs./hr., 650 lbs., 740°F. steam, Riley Steam Generating Unit

FEBRUARY - 1937 Humble Oil & Refining Co., Baytown, Texas, 1-350,000 lbs./hr., 675 lbs., 740°F. steam, Riley Steam Generating Unit

• • GOOD NEWS TRAVELS FAST • •



gas are absorbed as calcium sulphite and calcium sulphate, and the washing liquor becomes charged with these relatively insoluble compounds. As soon as the respective saturation points are exceeded, the two salts are precipitated. If this precipitation were allowed to occur within the scrubber, its packing would soon become choked beyond control. Therefore, workability of the scrubbing process is conditional upon providing a method of operation which prevents precipitation in the scrubber proper, and instead deliberately causes precipitation in a part of the recirculating system chosen and specially designed for this purpose.

Solution of this problem is based upon the fact that slightly supersaturated calcium sulphate and sulphite both form comparatively stable solutions, in which crystallization proceeds rather slowly. By keeping the degree of supersaturation to an empirically determined limit at the scrubber outlet, and by passing the washing liquor fast enough through the scrubber itself, it is possible to hold over precipitation until the liquor has entered a series of large vertical delay pipes of considerable length. In these pipes, flow is sufficiently retarded to allow precipitation and settling out of the sludge from the slowly moving liquid. Sludge thus accumulating is continually withdrawn through drain lines and passed into a thickener plant from which the clarified liquor recovered is returned to the main liquor circuit.

An additional safeguard to avoid precipitation on the scrubber surfaces consists in making the scrubber packing of wood lath, as wood offers considerable resistance to surface-crystal formation. Actually, the danger of scaling exists only in a comparatively small part of the scrubber, as about 50% of the SO_2 is absorbed in the first or "coarse" cleaning stage, which contains only about 20% of the entire scrubber surface. Because of the counterflow arrangement used, this first cleaning stage is identical with the last stage of liquor flow in the scrubber.

Design of the scrubber can be seen from the flow diagram, Fig. 5. This shows a complete washer unit designed to treat flue gas of one of the six 22,680-sq.ft. stoker-fired Stirling boilers thus far installed. The underfeed stokers are 18 retorts wide and have 708 sq.ft. of projected area. Two scrubbers, each connected by a separate gas duct to one of the two Ljungstrom horizontal rotor-type air preheaters per boiler, receive flue gas at 300 F. Each scrubber is further subdivided into two equal parts operating in parallel. Thus the entire gas flow from the boiler is split up into four separately scrubbed parallel streams. Flue gas is passed vertically upwards through the scrubber against the down flow of washing liquor.

For the sake of maximum scaling resistance, the first stage of coarse cleaning is composed of vertical suspended wooden plates arranged with a horizontal clearance of about 4 in. between plates. The second stage consists of a pile of laths stacked in crosswise layers. Here the gas is broken up into a large number of highly turbulent streams which come into intimate contact with the washing liquor trickling down over the packing. The flow area through the packing has been so chosen that gas velocity through the dry tower would approximate 5 ft. per sec., which gives efficient scrubbing without excessive draft loss. Having passed the packing, the flue gas enters a chamber in which rain is produced by a wooden liquor-distributing grid which forms the chamber ceiling; upon this ceiling the liquor is discharged by a number of nozzles distributed over the bottom of the head tank.

The clean-gas outlet is at one side

of the rain chamber, as shown in Figs. 2 and 5, is provided with a lath grid several rows deep to separate out moisture from the leaving gas. This is particularly important in view of the fact that the exit-gas temperature has fallen to 124 F. Fig. 5 shows the complete circuit of the washing liquor. After its passage through the scrubber the liquor is collected in the hopper bottom of the apparatus, from whence it is discharged into the circulating mains leading to the vertical delay pipes.

Fresh milk of lime required to maintain alkalinity of the liquor is injected through needle valves operated by an alkalinity-control system consisting of a thermionic potentiometer and a recording potentiometer controller which, besides providing a record of the pH value, automatically actuates the needle-valve gear. For this purpose the recording potentiometer is provided with an interrupter device arranged to give an impulse to the needle gear at intervals of 15 to 165 sec., which results in a valve-opening-speed range of $3\frac{1}{2}$ to 41 min. To allow more rapid needle-valve operation in the event of sudden and considerable load changes, this automatic control system is supplemented by a duplicate needle valve equipped with push button control.

Rate of flow of recirculating liquor is 15,600 g.p.m. per boiler. There are two recirculating pumps per washer working in parallel at constant speed against a liquor head of 30 ft. The entire washer system is arranged so that on reduced boiler load half of one washer can be in operation with one recirculating pump in service. Should the supply of make-up liquor from the mixed-liquor tank fail, an emergency makeup system goes automatically into operation and feeds river water into the washer affected to replenish losses due to sludge disposal and evaporation.

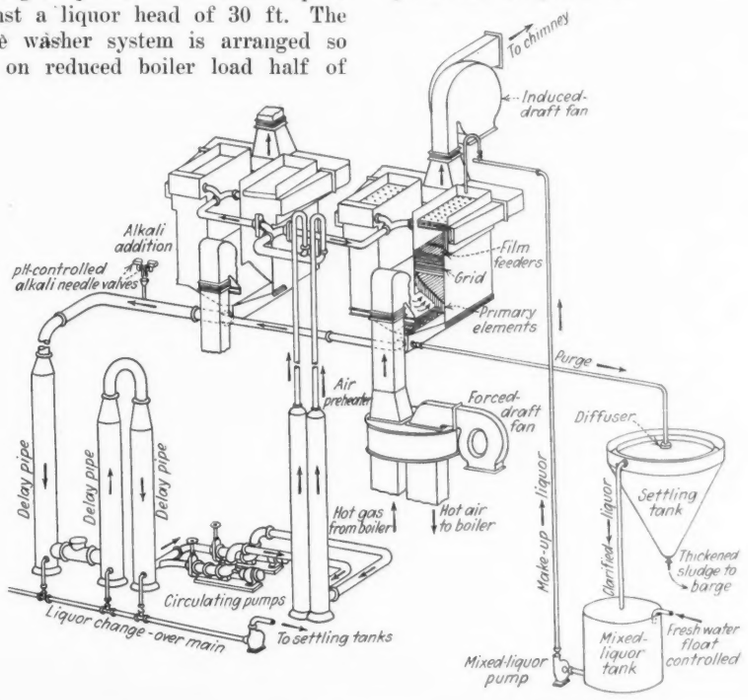
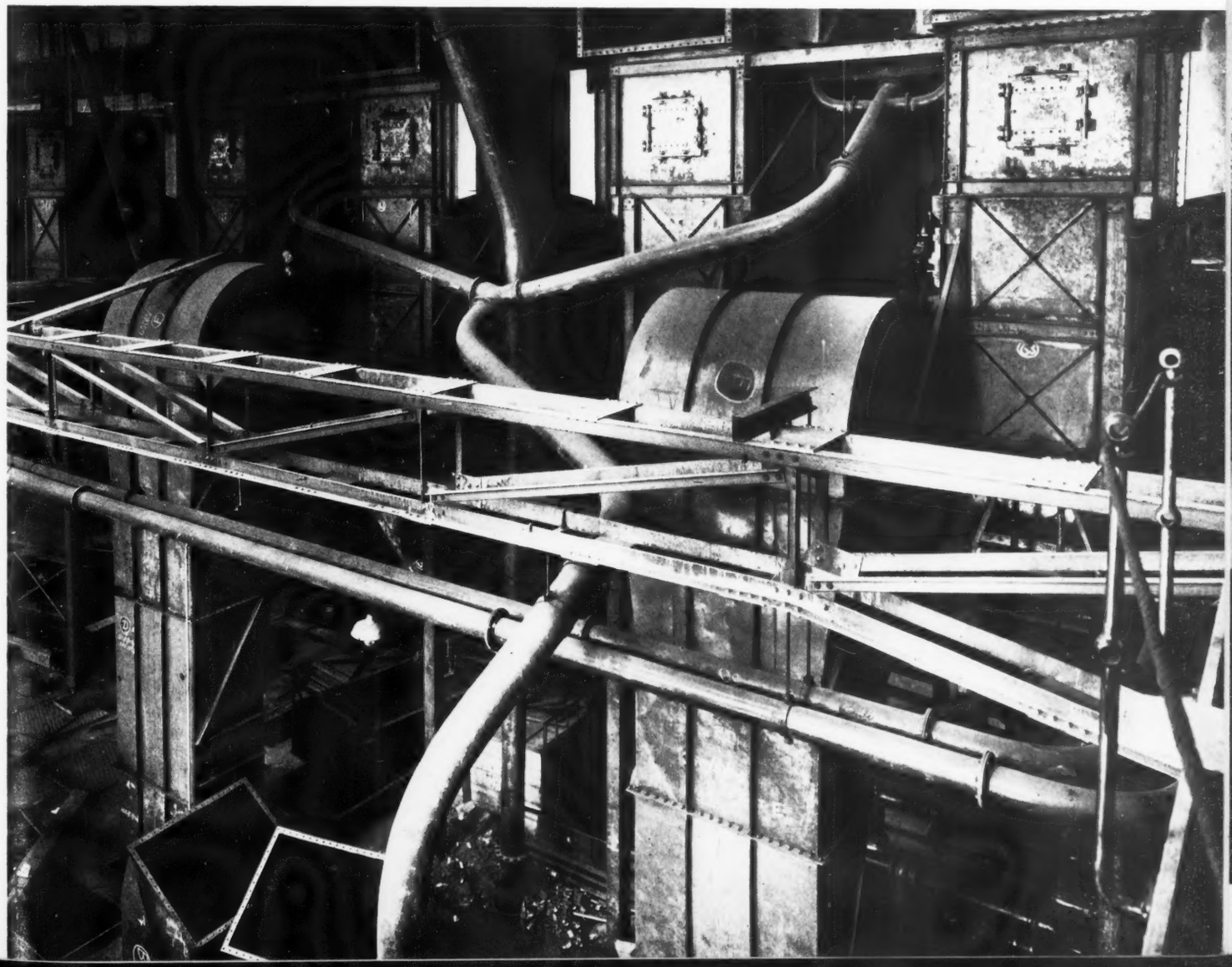


Fig. 3 (left)—Forced-draft fans and air preheaters. Fig. 4 (below)—Scrubbers are shown on both sides of the flue risers from the air preheaters. Fig. 5 (at right)—Flow diagram of scrubber liquor

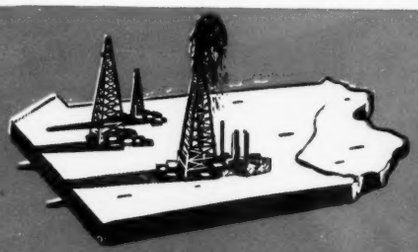


"NOW WE CAN'T FIND

TIDE WATER

INDUSTRIAL TYCOL OILS-GREASES

The Flying Yankee, Crack Train of the Boston and Maine and Maine Central Railroad, is one of many Diesel powered units lubricated with Tide Water Diesel Lubricants.



100% PARAFFINE BASE CRUDE *assures* HIGHEST FLASH POINT

ENOUGH SLUDGE TO FILL GRANDMA'S THIMBLE"

THIS DIESEL OIL LASTS TWICE AS LONG

"Before standardizing on Tide Water Diesel Oils we had found it necessary to change the oil every six months. Each time we opened up the engine there used to be an accumulation of sludge that was so great we considered it dangerous," said the Master Mechanic of a large manufacturing concern.

"By using Tide Water Oil in our 600 kw. Diesel units we are able to run steadily for a whole year without an oil change . . . and could run much longer. We can't find enough sludge now to fill grandma's thimble."

"Grandma's thimble" is an apt expression characterizing the result of the superior refining of Tycol Diesel Oils by the Edeleanu process. An ever-increasing number of satisfied users appreciates the unusually high stability and freedom from harmful residues that would tend to oxidize in service. Long, economical performance in Diesels of all kinds is assured by these 100% paraffine-base oils. They are furnished in a viscosity to suit every operating condition.

A comprehensive 48-page analysis of Diesel lubrication and fuel requirements is yours for the asking. We welcome an opportunity for a Tide Water engineer to survey your needs, and tell you what we have done for others . . . what we can do for you . . . with lubrication engineered to fit the job.

TIDE WATER ASSOCIATED OIL COMPANY
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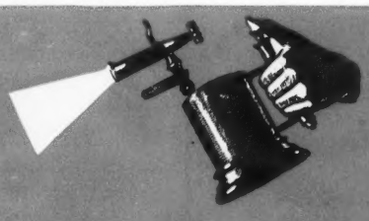
DIESEL OIL

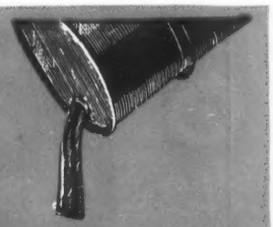
THERE IS A COMPLETE LINE OF TYCOL LUBRICANTS SCIENTIFICALLY ENGINEERED FOR EVERY INDUSTRIAL USE

FLATTEST TEMPERATURE VISCOSITY CURVE



AND GREATEST RESISTANCE TO BREAKDOWN

giving

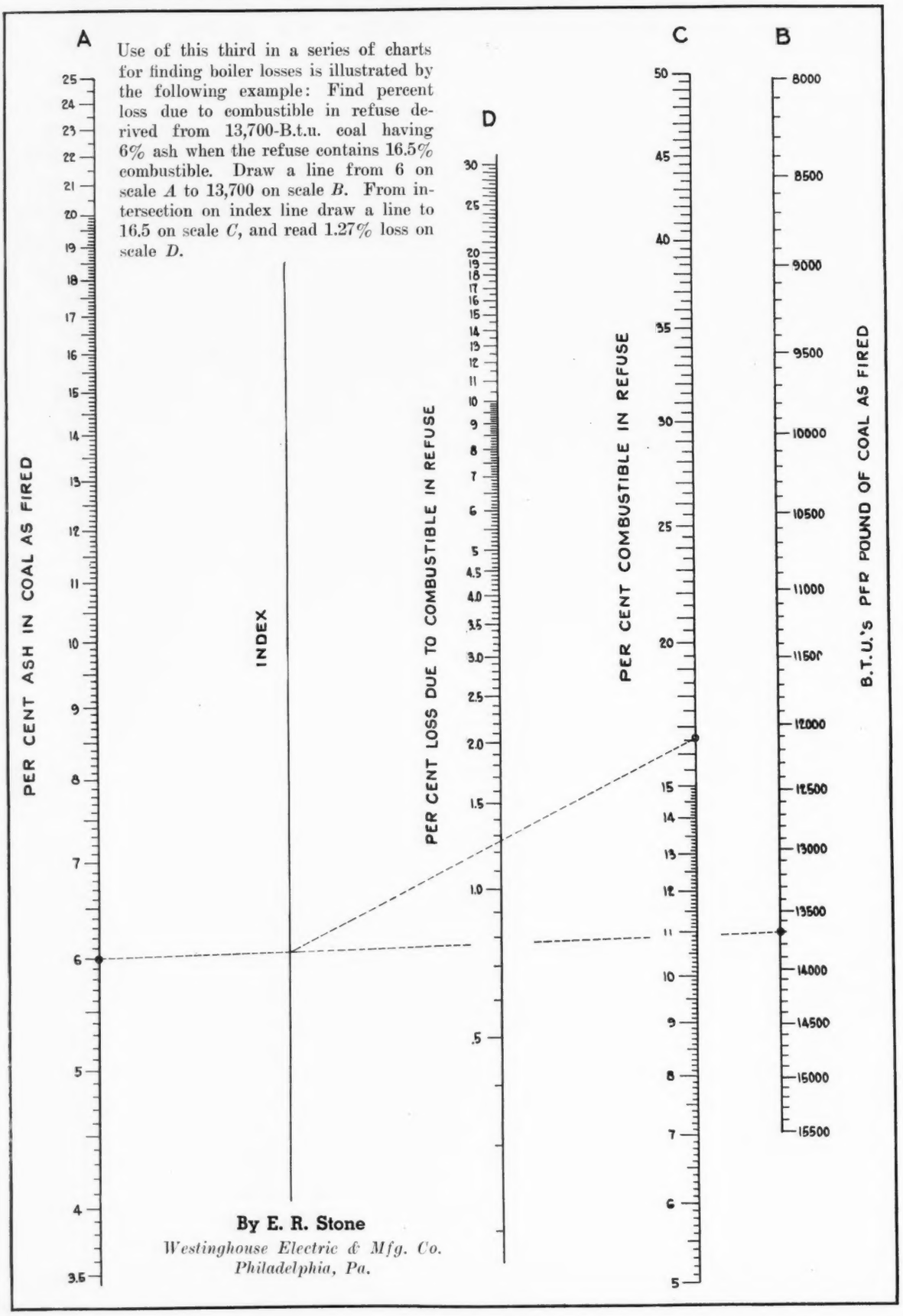


MAXIMUM ECONOMY AND PROTECTION FOR EVERY LUBRICATING DOLLAR

Number 58

Loss Due to Combustible in Refuse

Use of this third in a series of charts for finding boiler losses is illustrated by the following example: Find percent loss due to combustible in refuse derived from 13,700-B.t.u. coal having 6% ash when the refuse contains 16.5% combustible. Draw a line from 6 on scale *A* to 13,700 on scale *B*. From intersection on index line draw a line to 16.5 on scale *C*, and read 1.27% loss on scale *D*.



By E. R. Stone
Westinghouse Electric & Mfg. Co.
Philadelphia, Pa.

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PRACTICAL AIDS TO OPERATION

Log Sheet Keeps Operators on the Job

A POPULAR conception of some plant managers is that log-sheet records are of value only for test purposes. This is true as far as it goes, but these records also provide a means of keeping a check on the human element. With the development of automatic mechanisms for control of combustion, feedwater, load, etc., the number and frequency of manual operations have been reduced greatly. Frequent observation of all indicating and recording instruments, and inspection of bearing temperatures of fans, pumps and other rotating equipment comprise a large part of the operator's duties in a modern plant. Equipment under his supervision is usually in various locations in the building. The more traveling necessary for this routine inspection tour, particularly on a night shift, the greater is the tendency for some operators to neglect it.

While the only permanent cure for the latter condition is for the engineer in charge to weed out deficient members of the operating personnel, a log sheet is helpful. Hourly readings and recording by the operators of all important pressures and temperatures is required. Indicating and recording instruments should be provided at advantageous points, especially in the vicinity of all important equipment. The operator, unless utterly incompetent, hesitates to walk past the equipment to take a reading without observing its condition. Before going off shift, the operator should mark down any unusual conditions under remarks, and sign the log, placing himself personally responsible for any difficulty arising from neglect in his department.

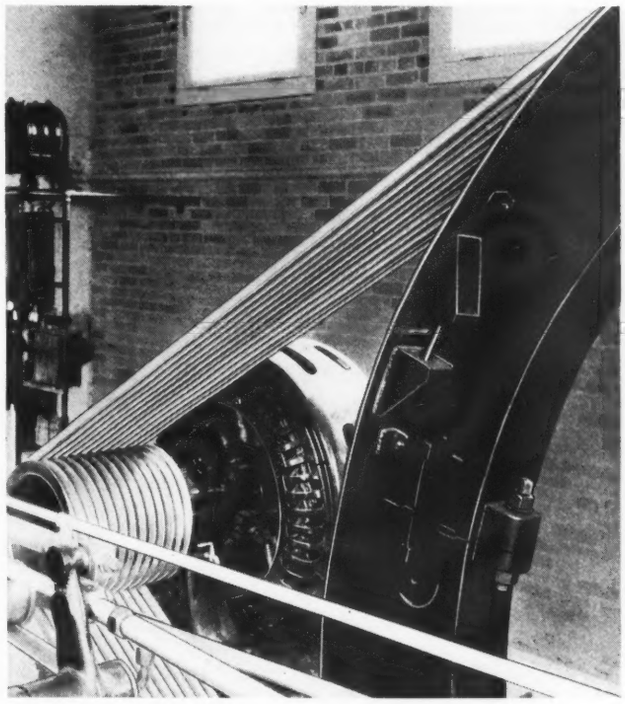
Chicago, Ill. R. O. BILLINGS

Reduces Power Costs by $4,000 Annually

UNTIL RECENTLY, the El Paso Laundry and Cleaners, Inc., purchased its power and produced steam for heating and process with a gas-fired Scotch marine boiler. Then, a 175-hp. corliss engine, suitable for the boiler pressure, became available in the El Paso market. This interested George Harvie, superintendent of the plant, who also located a 100-kw., 720-r.p.m., 220-volt generator that might be used with the engine. An engineering study of the problem showed that a very large saving could be made by first passing the steam through the engine, before it went to process. Several obstacles, however, had to be overcome before this plan could be carried into effect.

The engine, which formerly had been directly connected to an ice machine, operated at 90 r.p.m. and had a 12-ft. flywheel with a face too narrow for a belt drive from engine to generator. Moreover, the center distance between engine and generator shaft had to be short. Our district engineer was called in on the job and, with Mr. Harvie, worked out the solution shown in the photo.

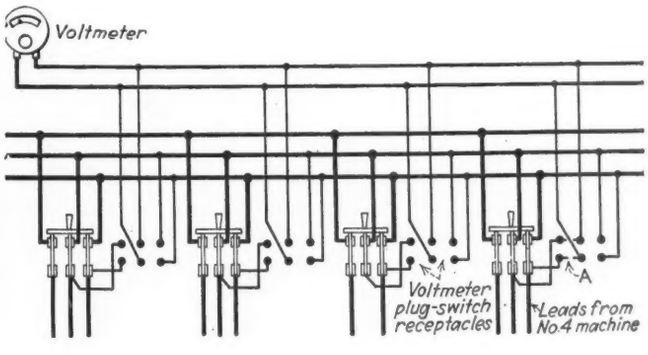
A $\frac{3}{8}$x21-in. band for the flywheel was made in two semi-circular pieces with welded lugs for drawing it tightly in place with bolts. After the band was bolted



in place, it was attached to the flywheel face with countersunk screws and then its ends were welded together and ground smooth. A grooved sheave was put on the generator shaft for connection to the engine flywheel by a 12-strand multi-V-belt.

At the end of the first month's operation, it was found that increase in the gas bill for boiler fuel was scarcely noticeable, leaving practically all the saving in power costs, $350.00 per month, as a return on the investment, which will pay for the installation in a comparatively short time. M. NASBY,

Denver, Colo. *The Gates Rubber Co.*



Misplaced Voltmeter Plug Causes Loss of Load

DOUBLE-ACTING gas engines directly connected to alternators serve as prime movers in one plant. Because of load fluctuations, governing of these engines is not as accurate as could be desired. For safety, a spring-loaded trip is mounted in the flywheel to open a circuit breaker in the ignition circuit in case of overspeeding. When once opened, the circuit breaker has to be closed

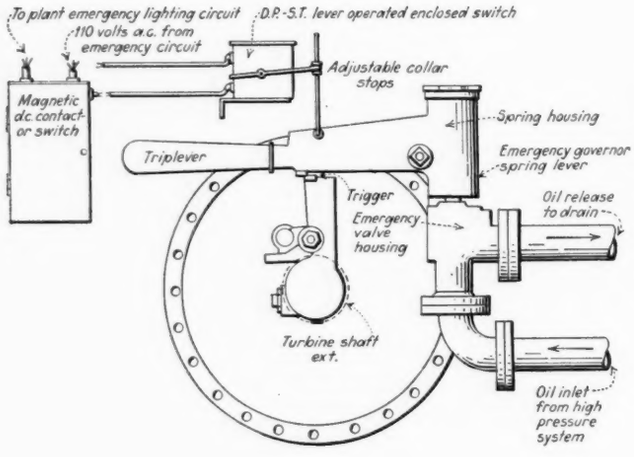
manually before the engine can go back into service. One day, load was dropped suddenly, causing the ignition circuit breaker to open on No. 4 unit. Two other units on load began to slow down.

The engineer saw that No. 4 unit wattmeter registered zero and tripped the generator circuit breaker, but load was still too much for the remaining two machines. To relieve them until they could come up to speed, two main feeder circuits were tripped off. The two engines then came to speed, but the voltmeter showed zero volts, although switchboard lights burned brilliantly.

Generator-voltage readings are taken by inserting a 4-pronged plug into the left position of the 6-hole receptacle, and for bus voltage in the right-hand position. The voltmeter plug had been left in the receptacle, as shown at *A*. As long as the switch was closed on No. 4 machine, the voltmeter showed bus voltage, but when the switch was opened, it indicated voltage in the generator leads which gradually went to zero as the machine slowed down. It was suspected that a fuse in the main ignition was blown, but only the safety circuit breaker was open. It was then closed, the unit brought back to speed, synchronized with the other two machines and the rest of the load picked up.

This incident shows how a small error may cause a lot of trouble. Somebody left the voltage plug in the wrong place. It should have been transferred to the right-hand position as soon as the incoming machine was synchronized and on load. The operator should have checked the trip as soon as he saw No. 4 unit drop its load and the other machines slow down. This could have been done much more quickly than pulling the breakers at the switchboard.

Coffeyville, Kan. EARL PAGETT



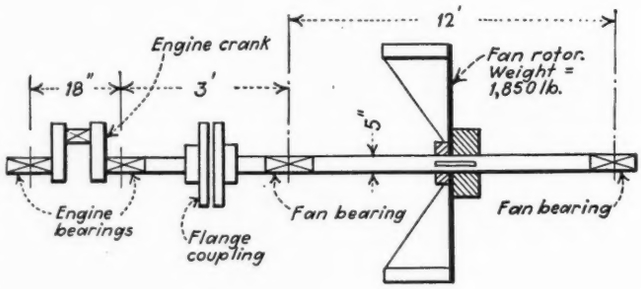
Control for Emergency D.C. Lighting Circuit

MANY of the larger power plants have an emergency house lighting system operated from a storage battery floating on the line. Under normal operating conditions, house lighting service is supplied through switching and transforming equipment from the a.c. bus. Should the normal source of power fail, the d.c. circuit supplies lighting service for getting the plant back into operation.

In one plant, the generator supplied several outside transmission lines as well as station power and lighting. Being in a section where electrical storms were frequent, some difficulty was experienced with load dropping and having the turbine start to race. The emergency governor would trip and often the station would go dark until the d.c. circuit could be switched on.

A magnetic throw-over switch was installed. While this usually worked, there were times when it would stick or otherwise fail to operate when most needed. As practically every failure was the result of an overspeed trip, it was decided to install an additional d.c. lighting control, operated directly from the turbine. The lever-operated switch energized the contactor coils, which in turn directly operated the d.c. lighting-circuit contactor. This control was connected in parallel with the older magnetic switch not shown. Since its installation, no trouble has occurred with the emergency lighting. Both controls are tested weekly to check on their condition.

Columbus, O. J. R. WILLIAMS



Fan-Shaft Misalignment Stops Engine Knock

IN ONE of our buildings, the main heating unit is a low-pressure steam-engine-driven fan distributing tempered air to all rooms. From the time the unit went into service, the engine had a knock. In an effort to stop knocking, connecting-rod and main-engine bearings were adjusted, the engine and fan shaft realigned, and the engine regrouted to its foundation, but without results. Steam-pipe supports for this pipe, about 60 ft. long, were changed from ceiling to floor but the knock continued. The engine knock was being transmitted to the various rooms in the building and was very objectionable, so that something had to be done to correct the fault.

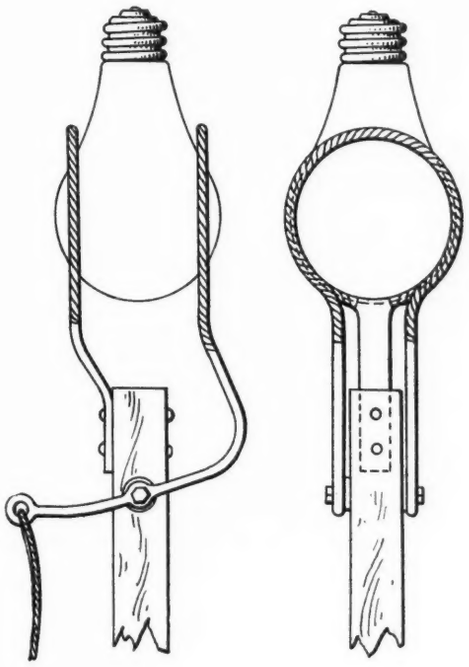
I was assigned to investigate this trouble and, if possible, to suggest a solution. An examination of the unit showed everything to be in first class mechanical condition and I began to look for something unusual. The horizontal, center-crank engine has a bearing on each side of the crank and the fan also has a bearing on each side. This required that all four bearings be absolutely in line, a very difficult thing to accomplish in equipment of this type. It was my conclusion that the only way a knock could be caused in this engine was by something being out of line.

When examining the fan, I noticed the unusual length, 12 ft., between its bearings and that the fan-rotor was located centrally between bearings and the point to cause maximum shaft deflection. I computed the fan rotor weight and found it to be about 1,850 lb. Then, applying the structural formula for deflection at the center of a beam, I found that shaft deflection was 0.1 in. This was putting the fan shaft out of line at the

flange coupling and causing the shaft to whip, transferring the knock to the engine.

On this hypothesis, we raised the outer bearing of the fan $\frac{1}{8}$ in. so that the inside end of the shaft would always run level with the engine, even though the outside end would be much out of line. The change eliminated the engine knock and, in a period of over three years, no further trouble has been experienced.

Kansas City, Mo. W. H. BURLEIGH



Extension Grip for Replacing Lamps

FOR REPLACING lamps in ceiling fixtures in our plant, I made the device shown in the drawing. It comprises two rings made of $\frac{1}{4}$-in. rod. One ring is welded to a piece of strap iron bent and bolted to a long hickory handle; the other is welded to two $\frac{1}{4}$-in. rods, bent and hinged on the handle. Rod ends are welded together and a strong cord tied to them. This cord runs to the operating end of the stick where 6 nails are driven, spaced about 2 in. apart. A loop in the cord is slipped over the nail that will put a firm grip on the lamp. Rings are wrapped with tape to grip the lamp as it is being screwed in or out.

Kearney, Neb. ED SWAN

How Should a Globe Valve Be Installed

SOME YEARS ago a chief engineer and I raised the question of whether or not a globe valve should always be installed with pressure below its disk when closed. With pressure on top of the disk, the valve can be repacked only when open; when pressure is under the disk, the valve can be packed either open or closed. This is a good reason for the general practice of installing globe valves with pressure under the closed disk.

Closed valves in medium- and high-pressure lines, however, may give trouble when they cool off on the outlet side. This applies particularly to soot-blower valves, valves on drips and others with outlets leading to atmosphere. When such valves cool, they may leak as they contract and allow steam to escape under the disk. When a valve is installed so that pressure comes on top of its disk when closed, its stem cools less and pressure tends to hold the disk on its seat.

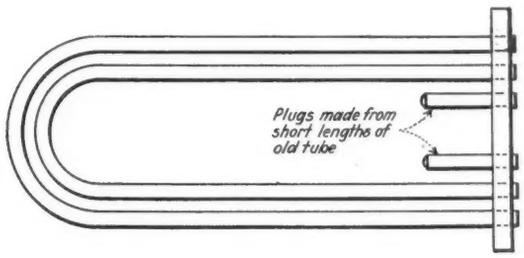
However, a globe valve used as an engine throttle, should it fail, will close automatically and stop the engine, if pressure comes on top of the disk. If pressure is applied under the disk, the valve will be forced open, making it impossible to stop the engine. In boiler-feed lines, globe and angle valves should be installed with pressure under the disk, for if pressure is on top of the disk, the valve will close and shut off water flow to the boiler should a valve stem fail.

These are some of the reasons for and against putting globe valves with pressure under their disks, when valves are closed. Perhaps other *Power* readers have their own ideas on the subject.

Whitby, Ont. EDWARD A. CLAMP

Permanent Plugs for Water-Heater Tubes

A COPPER TUBE in the heating element of one of our water heaters developed a bad leak when it was imperative to keep the heater in service with as little delay as possible. Similar trouble had developed previously on other heaters, on which we had removed tubes and filled holes with wooden plugs fastened in with bolts and washers. These worked satisfactorily for a short



time until the wood became soft. Moreover, too much time was spent in removing the manhole cover and entering the heater to insert the plugs. Therefore it was necessary to find some way of making a permanent repair that would not require taking the heater out of service for very long.

We had an old tube, in the scrap pile, that had been removed from another heater, so we decided to make some plugs from it. Two 4-in. pieces and one 1-in. piece were cut from this tube and the 1-in. piece split in two parts. These pieces were flattened and two disks cut from them that would just fit inside the 4-in. pieces, one disk in each plug. Disks were brazed into place with Tobin bronze after the parts had been treated in a dilute solution of hydrochloric acid to remove all dirt and scale.

The defective heater tube was then cut out and its end pushed in and to one side of tube holes. Tube plugs were then inserted and rolled into the holes as in the figure. Care should be taken not to make plugs longer than necessary for the tube-roller pin. If made too long, there is danger of setting up a water hammer in the tubes because of lack of circulation.

Cleveland, O. THOMAS C. BROCK

CURRENT COMMENT

What Capacity Freon Compressor?

ATTENTION should be called to several errors in the answer to "What Capacity Freon Compressor?," page 40, Jan. *Power*. First, in a volatile liquid such as Freon, heat is abstracted by evaporation of the liquid and not by an increase in temperature of the refrigerating medium. Therefore, under the conditions stated in the question, 218.5 lb. of Freon is the actual amount circulated per hour to produce one ton of refrigeration. Total weight circulated per hour equals 150 x 218.5, or 32,775 lb., assuming that vapor leaves the evaporator in a saturated condition.

If vapor is superheated 10 deg. after leaving the evaporator, volume per lb. of vapor is 0.84 cu. ft., and volume handled by the compressor is 0.84 x 32,775, or 27,521 cu. ft. per hr. Using the assumption stated in the article that the volumetric efficiency of the compressor is 90%, compressor displacement is 27,521 divided by 0.9, or 30,580 cu. ft. per hr. The author erred again in adding 10% to the delivery value instead of dividing by 0.9.

It is absurd to allow 3% for impurities, because weight of impurities circulated would amount to almost half a ton per hr. If the system in question contains any detectable amount, something ought to be done about it.

Painted Post, N.Y. RALPH VOGGENTHALER

Life May Begin at 60

SOME TWO years ago, I lost my position in a large central power station when the plant closed down, and after looking and hoping without much success, I was informed by a friend of a vacancy in a small manufacturing plant in southern Massachusetts. It was a one-man plant, a 12-hour-a-day job, and had been regarded as a temporary meal ticket by engineers who had been forced by circumstances to take the position.

The plant is owned by an estate and is managed by ladies who installed their former chauffeur as night watchman. Because of the rapid turn-over of engineers, they had come to depend strongly on this jack-of-all-trades, whose knowledge of steam and power matters reminds me of a story I once heard about a young colored man who was fireman and general factotum in a small apartment building. An engineering-supply salesman entered the boiler room one day in search of business, and finally found the fireman hiding behind a pillar. When asked what was the matter, the colored man replied, "I tells you, Boss, I'se afraid of that there boiler."

The salesman glanced at the gage and noting a reading of 60 lb., began to laugh at the fireman. Whereupon the colored man indignantly replied, "Dat so, Boss? Dat hand done gone around twice already!"

Of course, this sort of situation made it very pleasant for the engineers, all of whom immediately adopted the arm-chair-and-I-should-worry attitude, completely ignoring the fact that the plant offered a good opportunity for reducing operating costs. The steam plant consists of two oil-fired h.r.t. boilers, a 150-hp. corliss engine, three wheezy steam pumps, and two decrepit power pumps—enough to discourage any man. The squeaks, squawks, and bass groans of this outfit would have made a best seller, if published as modern jazz.

The engine was operated condensing the year around, regardless of the fact that all available exhaust steam could be, and now is, utilized in manufacturing and heating. This item, plus increased boiler and furnace efficiency, with other details cared for with which all engineers are familiar, has reduced the fuel bill 56%—roughly, $3,000 per year. The savings have been made at a total cost of less than $500 for new installations and repairs, plus about 80 hours work on my part over a period of two months.

Now, after five months, my salary has been increased, the night watchman has been placed entirely under my supervision, and I find myself, at the age of 60, in very congenial surroundings, with adequate compensation and security for old age—as secure as security can reasonably be. And as I travel about and notice many smokeless stacks and vacant buildings, I can't help thinking that the arm-chair-and-I-should-worry attitude is responsible.——*Anonymous*

Plant Operator's Shift Schedule

"PLANT Operator's Shift Schedule," March *Power*, prompts me to submit the schedule used in our plant, an arrangement which has interested many visiting engineers. In 1933 we were requested to place our operation on a 40-hr. week basis and the schedule given here was put into effect and is still in use. The system is applicable to any 7-day-per-week operation with any number of shift operators, but preferably in groups of 5, and requires 4 complete crews with one general utility relief man for each group of 5.

Each operator works for 5 successive days at 8 hr. per day, then is off two days in succession and upon returning to work, changes shifts progressing forward. The general-utility relief man *X* is due for promotion to shift engineer when the first vacancy occurs and the variety of work he encounters under this schedule provides desirable training. His first shift of the week is as assistant, which allows him to become acquainted with any new phase of operation under supervision of the regular shift engineer.

Each operator gets the same two days off each week, but classifications could be changed as often as advisable. We change only twice per year, at which time the schedule is posted for two or three days, giving the shift engineers new letter classifications which are taken by their original crew. The shift engineer does not have his own crew with him the entire week, but we find this mixing of crews promotes a better exchange of ideas on operating problems.

Camas, Wash. O. T. DEFIEUX

	ENGINEER			ASSISTANT			OILER			NO. 1 FIREMAN			NO. 2 FIREMAN		
TIME	8-4	4-12	12-8	8-4	4-12	12-8	8-4	4-12	12-8	8-4	4-12	12-8	8-4	4-12	12-8
SUNDAY	A	C	B	A	C	B	D	C	B	D	C	B	D	C	A
MONDAY	A	C	B	A	D	B	A	C	B	D	C	B	D	C	B
TUESDAY	A	D	B	A	D	X	A	C	B	A	C	B	D	C	B
WEDNESDAY	A	D	X	A	D	C	A	D	B	A	C	B	A	C	B
THURSDAY	A	D	C	B	D	C	A	D	X	A	D	B	A	C	B
FRIDAY	B	D	C	B	D	C	A	D	C	A	D	X	A	D	B
SATURDAY	B	D	C	B	A	C	B	D	C	A	D	C	A	D	X
SUNDAY	B	A	C	B	A	C	B	D	C	B	D	C	A	D	C
MONDAY	B	A	C	B	A	D	B	A	C	B	D	C	B	D	C
TUESDAY	B	A	D	X	A	D	B	A	C	B	A	C	B	D	C
WEDNESDAY	X	A	D	C	A	D	B	A	D	B	A	C	B	A	C
THURSDAY	C	A	D	C	B	D	X	A	D	B	A	D	B	A	C
FRIDAY	C	B	D	C	B	D	C	A	D	X	A	D	B	A	C
SATURDAY	C	B	D	C	B	A	C	B	D	C	A	D	X	A	D
SUNDAY	C	B	A	C	B	A	C	B	D	C	B	D	C	A	D
MONDAY	C	B	A	D	B	A	C	B	A	C	B	D	C	B	D
TUESDAY	D	B	A	D	X	A	C	B	A	C	B	A	C	B	D
WEDNESDAY	D	X	A	D	C	A	D	B	A	C	B	A	C	B	A
THURSDAY	D	C	A	D	C	B	D	X	A	A	B	A	C	B	A
FRIDAY	D	C	B	D	C	B	D	C	A	A	X	A	D	B	A
SATURDAY	D	C	B	A	C	B	D	C	B	A	C	A	D	X	A

Date, Shift Change	A	B	C	D
8=25=33	Smith	Brown	Riley	Olsen
2=25=34	Riley	Olsen	Smith	Brown
8=26=34	Brown	Smith	Olsen	Riley
2=24=35	Olsen	Riley	Brown	Smith
8=25=35	Smith	Brown	Riley	Olsen
2=23=36	Riley	Olsen	Smith	Brown
8=23=36	Brown	Smith	Olsen	Riley
2=21=37	Olsen	Riley	Brown	Smith

READERS' PROBLEMS

QUESTIONS for Our Readers

Removing Soot from An Economizer

Question 1

OUR *economizer is provided with a soot hopper, from the bottom of which soot is piped to our ash-disposal system. A water connection is provided in the hopper for sluicing soot down the pipe. We experience considerable difficulty with plugging of this line, and find it necessary to take the line down to clean it. Can* POWER *readers suggest how this trouble can be eliminated or made less bothersome?*—H.C.S.

Air-Compressor Diaphragms

Question 2

THE *rubber diaphragms in our air-compressor unloaders have a very short life. Can any one tell me of a substitute that would be sufficiently flexible and give longer service?*—E.F.V.

Suitable answers from readers will be paid for if space is available for publication.

COAL STICKING IN SILO

ANSWERS to April Question 1

The Question

DURING *wet weather, coal hangs up in our 80-ft. high concrete coal silo, and must be barred down by hand. Does anyone know of some way to prevent coal from sticking to the side walls?*—S.S.D.

Paint Silo Walls

THE QUESTION fails to state whether coal is sized and graded or is all fines. If the former, coal piled within the silo forms a cone into which it is only necessary to dump an occasional skip of walnut or larger lump coal. These lumps will roll down the slope of the pile and arrange themselves along the silo walls, effectively preventing bridging or formation of overhangs. I first saw this used on a ship where the Scotch engineer bribed coal-dock employees to run in an occasional barrow of lump coal with the poorest-grade slack that the captain always bought.

If the coal is fine and so thoroughly graded that it cannot of itself form a fringe of lumps, washing down the walls and painting them with two or three coats forms a tough, waterproof surface that will do the job. This will prevent the initial bond between wet coal and the more or less rough concrete face of the silo.

As the silo is evidently open at the top, it may be necessary to hose down bad spots to halt any tendency towards bridging. If water must be kept from coal as much as possible, silo walls may be drilled at spots where accretions form, and air jets installed which will quickly break down any tendency for coal to accumulate. Still another method, which has worked satisfactorily in preventing bridging in a rectangular storage bin for cement, is to hang a heavy chain in each corner of the bin. Each chain should be at least twice as long as the bunker is deep. As coal is put into the silo, the chain is gradually run in, so that it is held in a series of loops or reverse bands. Then, as the bin is emptied, the chain is lifted to break up any mass of cement that may adhere in corners. Although I have never seen this scheme applied to coal storage, it should work effectively and do away with any need for men to enter the silo and barr down coal by hand.

Longview, Texas ELTON STERRETT

Rope and Pointed Bar Will Break up Arches

IN OUR PLANT, a large southern industrial, we have had much of S. S. D.'s trouble and as yet have found no complete solution. The coal burned is New River slack with a large percentage of extremely small particles. As long as this fuel is moved directly from cars in which it is received to the silo, very little trouble with hanging up and arching over is experienced.

When it becomes necessary to use coal from storage, trouble starts. The only explanation is the greater quantity of surface moisture in stored coal or the tendency of fines and larger particles to segregate with repeated handling.

We have found that sticking in the silo can be minimized if walls are thoroughly cleaned whenever possible. A heavy pointed bar on the end of a rope is an effective way of breaking through arched coal from above. The rope should be long enough so that the bottom of the silo can be reached. Also, the rope end should be fastened securely to prevent loss of rope and harpoon when coal begins to slide or the bar breaks through the arching coal.

S. H. COLEMAN
Roanoke, Va.

DIESEL CAPACITY

ANSWERS to April Question 2

The Question

OUR *industrial diesel plant contains three slow-speed 300-kw. diesel sets. Demand is normally about 500 kw., but may rise to 700, and overnight and on weekends drops to about 75. It has been suggested that a 100-kw. high-speed diesel set would be able to handle peaks (with two present engines running), and could handle the weekend load alone. Considering the fact that we already have 900 kw. of capacity in three units and that the difference between combustion efficiency at half and full load on a diesel is relatively small, I don't feel that the additional unit is justified. Again, if we replace one 300-kw. unit with the 100-kw. set, load growth within the next year or two may give us insufficient capacity, and there is ever-present the necessity for running all three units at full load in order to meet a 700-kw. demand. Have* POWER *readers anything to suggest from their experience with multi-engine plants? What are the factors to be considered and the general principles to be followed?*—R.E.T.

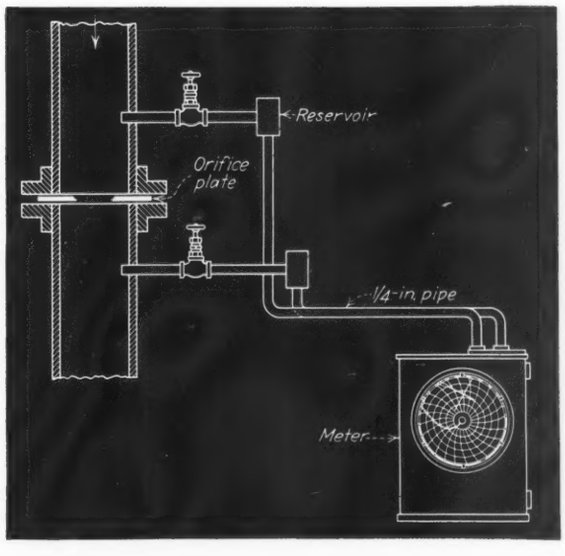
100-Kw. Set Would Increase Efficiency

THERE WOULD be a decided increase in efficiency if a 100-kw. set were installed. The 300-kw. diesel set, carrying a load of 75-kw., will deliver about 6½ kw.-hr. per gal. of fuel, whereas the 100-kw. unit would deliver 12 kw.-hr. Assuming 100 hr. per week of such operation,

WHAT'S WRONG WITH THIS PICTURE—XVI

Flowmeter Piping

THERE are at least ten errors shown in this drawing. Make a list of those you recognize, then compare with the list on page 350.



there would be a direct saving in fuel of 530 gal. per week, to say nothing of saving in lube oil and maintenance.

It is not necessary to worry about future load growth because a very efficient control has been developed which permits addition of high-speed units as demand increases. Parallel operation and automatic control of additional units is obtained through the medium of exhaust temperature and a simple application of an over-running clutch coupling between engine and alternator. The latter allows the alternator to float on the line as a synchronous condenser, which in this instance would result in increased over-all efficiency on heavy day loads.

Boston, Mass. G. B. BAILEY
Thermal Engrg. Co.

Substitute 150-Kw. Unit For 300-Kw. Machine

DURING base-load operation of two 300-kw. units with a 500-kw. load, an efficiency of 84% in fuel consumption can be expected. During existing peak operation with the addition of a 150-kw. unit, if space is available, a fuel efficiency of 93% may be secured; at night and over weekends, 50% efficiency may be obtained.

Most industries today are operating with single shifts of 40 hr., which, subtracted from the 168 hours in a week leaves 128 hours of operation at 25% load. This would cause fuel consumption of approximately 500 gal. more than would be used if a 150-kw. set operated at 50%. Another disadvantage in using the 300-kw. unit during off-peak loads, unless fuel-injection pressure is very high, is that possibility of carbon accumulation is very great.

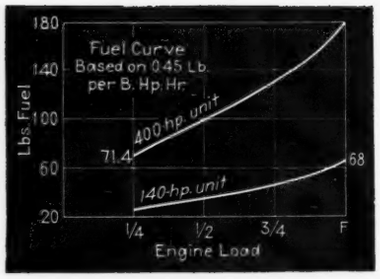
The additional unit should pay for itself and prolong life of the present units. Moreover, with the modern trend for more illumination, unit drives, additional equipment, etc., load will undoubtedly increase.

New York, N. Y. R. G. THOESEN

Never Overload Diesels For Best Results

IF R.E.T. will obtain fuel ratings for the different loads on his engines and also for a third high-speed 100-kw. set, he can make up fuel curves similar to the accompanying chart, in which curves are made assuming a consumption of 0.45 lb. of fuel per b.hp. hr.

A 140-hp. machine will use 68 lb. of fuel per hr. and the 400-hp. unit at 134 hp. will use 80 lb., a difference of 12 lb. which is 1.6 gal. of 7.5-lb. fuel. This, with fuel at $0.06 per gal., gives a saving of $0.095 per hr. for the smaller machine at higher load. Assuming a high figure for lube oil consumption of 0.0005 gal. per hp.-hr., we find that the large unit will use 0.2 gal. per hr. and the small unit 0.07 gal. With lube oil at 50 cents per gal., comparative figures are 10 cents per hr. for the large engine and 3½ cents for the smaller one, or a saving of 6½ cents per hr. for the small engine.



If engines are operated 96 hr. per week, a saving of $15.36 or $798.72 per yr. will be made if a 140-hp. engine replaces the larger one. The cost of such an engine is approximately $15,000; interest on this sum at 6% is $900.

Thus, the saving will not pay for interest on the investment in this case. Unless the 140-kw. unit can be operated more hours, it cannot be installed. Of course, R.E.T. has a peak of 700 kw., which he might pull with two of the large units and the small, which will put more operating hours on the small engine. The possibility of taking out one of the 300-kw. units can not be recommended because a diesel should never be overloaded for best service results.

I believe R.E.T. should leave his plant as is and not install a 100-kw. unit. As an alternative move, he might use purchased current for night loads and weekends.

Walthill, Neb. W. W. DINGWALL

Systematic Study Must Be Made

TO ASSIST R.E.T. in solving the problem of whether or not to change his present plant of three 300-kw. diesel units to two 300-kw. and one 100-kw. units, I suggest that he carry out the following study of his plant:

First, four or five typical weeks of plant running should be chosen that cover seasonal fluctuations throughout the year, and load curves plotted for them. The data for these curves may be taken from the daily log of watthour-meter readings, plotting kw.hr. vs. time of day. From these, a load duration curve for the year may be plotted—kw. demand vs. hours duration. The method for doing this is explained in an article "How Many Diesels—What Size", November, 1935 *Power*, page 592.

Secondly, fuel consumption of present engines should be determined, either from the plant log or by metering oil under operating conditions. From this data, a curve of fuel consumption per hr. vs. kw. load may be plotted. Similar information for a 100-kw. machine may be obtained from several engine manufacturers.

Then, a curve may be obtained by combining load-duration and fuel-consumption curves, and from the area under this curve of gal. per hr. vs. hours in the year, fuel consumption for the year may be computed. For the exact method of constructing this annual cost curve see "Variable Load Analyzing" by G. C. Boyer, July, 1935 *Power*, page 370.

When these fuel curves have been made up for 700- and 900-kw. capacity plants, fuel saving for the 700-kw. plant is very apparent. All curves, of course, should be based on the best operating schedule for load division among the machines.

If future plant growth is contemplated, it might be well to make up fuel-consumption curves for a plant with two 300-kw. machines and two smaller machines which would be capable of safely carrying probable loads. It might possibly work out, in view of frequent 75-kw. loads, that this would be the best answer. Two hours work on such curves would definitely settle the problem from the fuel-consumption point of view.

While a fuel-consumption analysis will probably show that a change will save money, there are other things to consider. When any one machine is down

(Continued on next page)

WHAT'S WRONG WITH THIS PICTURE—XVI

Flowmeter Piping—See Page 349

THE ERRORS shown in the flowmeter piping affect both the accuracy of the flow indications and the convenience of meter maintenance.

1. *Reservoirs Not at Same Level.* Whether the measuring orifice or nozzle is in a vertical or horizontal pipe, reservoirs should be at exactly the same level; otherwise the meter will be inaccurate.

2. *No Vent at Top of Reservoir.* Each reservoir should have a vent at the highest point to permit escape of air.

3. *Nipple to Bottom Tap Not Covered.* Insulation should be applied to the nipple forming the connection between the lower tap and the reservoir.

4. *Pipe to Meter Not Pitched.* To insure absence of pockets in the piping to the meter, there should be a pitch of at least 1 in. per ft.

5. *Connecting Pipe Too Small.* It is recommended that either ½-in. copper tubing or ⅜-in. iron pipe be used for flowmeter piping.

6. *No Open Blow at Meter.* A tee with open-blow valve near the meter is convenient for blowing dirt and air from the lines.

7. *No Shut-Off Valves at Meter.* Globe valves should be placed in both lines at the meter. This permits the meter to be shut off for testing without shutting off lines at the main.

8. *No Unions in Pipe at Meter.* Unions in both pipes at the meter below the shut-off valves are necessary so that lines may be opened when the meter is checked.

9. *Nipples Project Inside of Pipe.* To avoid swirls at tap connections, nipples should be flush with the inside of the pipe and all burrs should be removed.

10. *Orifice Plate Put In Backwards.* Beveled edge of orifice plate should be on the down-stream side.

for repairs or other emergency, remaining machines must carry the load if no interruption of service is to occur. A 300- and a 100-kw. machine cannot carry a 500-kw. load, which R.E.T. states is the usual demand. Therefore, if a 300-kw. engine was replaced by a 100-kw. unit, the other 300-kw. machine would have to be repaired and ready for service when the load passed 400 kw.

If machines of more than one size are used, spare parts of varying size must be kept in stock, which is a minor disadvantage. There are a few other factors to be considered, such as new machine first cost, old machine trade-in value, and space plus additional switchboard material if a fourth machine is added. All these factors must be considered in relation to each other if the correct answer is to be obtained.

Bronxville, N. Y. V. P. RADER

Recommends Keeping Three 300-Kw. Units

R.E.T. SEEMS to have analyzed his own problem pretty thoroughly. There might be some justification for adding a 100-kw. unit for night and weekend use, but certainly none for removing 300 kw. of capacity from a plant which already has an ideal day load. In the face of ever-increasing present-day demand for industrial power, it would not be good "economics."

Briefly, let us analyze factors governing the case. In the present "set-up" there are three 300-kw. units and a normal demand of 500 kw., leaving 100 kw. in reserve in the two machines on the line. This is ideal for good fuel economy and from the maintenance standpoint. Never run a diesel at full load continuously. In the event one of the machines in service requires shutdown for repairs, the spare machine can replace it.

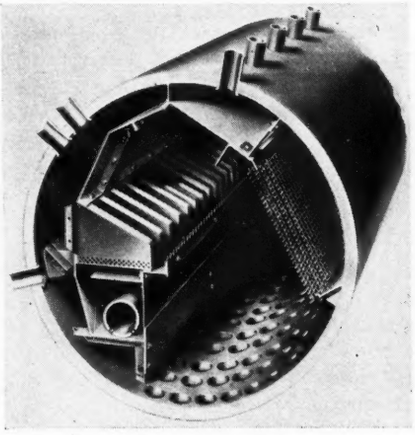
When demand increases to 700 kw., three machines are put in service, loading the plant to about 77% of its capacity. This again is a good load for fuel economy and does not overload engines.

If a 300-kw. unit is removed to make room for a 100-kw. unit, no opportunity is available for maintenance on either of the 300-kw. units unless R.E.T. likes to work nights. Assuming that demand increases to 700 kw., all three machines are loaded to capacity—never a wise plan. And if all three machines are loaded to capacity, there remains one of two alternatives: either "dump" part of load or transfer part to night shift.

With the original 300-kw. units, all load demands can be met easily, with the exception of the 75 kw. at night.

Vero Beach, Fla. H. D. WHITE

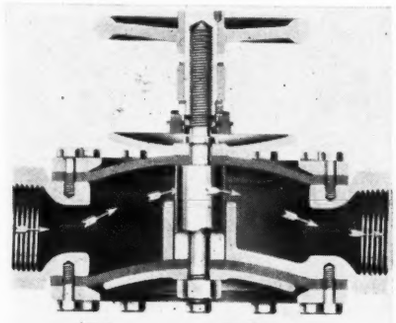
WHAT'S NEW IN PLANT EQUIPMENT



STEAM WASHER

ENTRAINED solids are removed from steam by forcing it to bubble through clean feedwater, which enters trough of washer through longitudinal perforated pipe and spills over notched weir. Steam entering drum through tubes is passed into hoods and out through apertures, bubbling through feedwater. Washing of steam is obtained also by mixing of steam and water between elements. Screen removes moisture that may be carried along with steam.

Combustion Engineering Co., Inc., 200 Madison Ave., New York, N. Y.



PIPE UNION

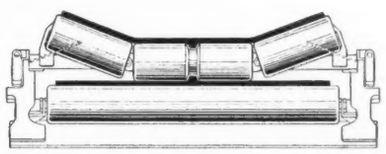
"DUALSTEEL" union said to have great tensile strength (80,000 lb.) and high resistance to corrosion. Completely "Parkerized", including threaded areas. Brinell hardness of 180. ¼- to 2-in. sizes.

Rockwood Sprinkler Co., 38 Harlow St., Worcester, Mass.

SELF-GUIDING BELT CONVEYOR

CONVEYOR BELT is molded with a continuous center-guide strip on underside. Illustration shows anti-friction idler with deep groove on central roller which confines guide strip on both runs. Manufacturer states that belt maintains central carrying position at all times, even when conveyor is tilted at a considerable degree, thus making side-guide idlers unnecessary. Made for all widths of belt, and with double guides for wider belts.

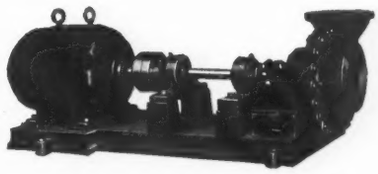
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.



BALANCED-DIAPHRAGM VALVE *(photo left)*

BALANCED valve eliminates bellows and stuffing boxes. Claimed unnecessary to remove valve from line to change diaphragm, which can be supplied of various compositions for air, water, gas, acids, or alkalis. Said to operate in any position, impregnable against freezing, and may be either hand or motor operated. 2-in. size and larger.

McAlear Mfg. Co., 1901 S. Western Ave., Chicago, Ill.



CORROSION-RESISTANT CENTRIFUGAL PUMP

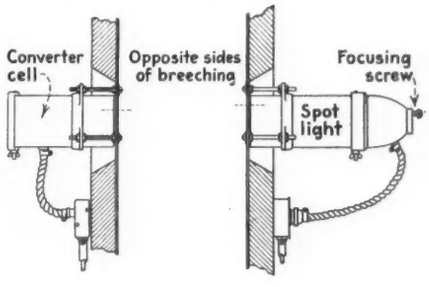
TYPE SC "Vortex" single-suction pump for corrosive liquids made in a wide range of corrosion-resistant alloys and metals. Construction material, however, is not selected until customer's needs are known. Ball-bearing construction, deep stuffing boxes, and vertical split casing. Bulletin D-46.

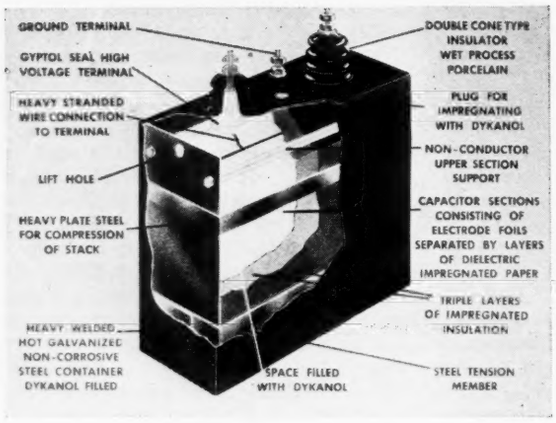
Lawrence Pump and Engine Co., P. O. Box 70, Lawrence, Mass.

SMOKE DETECTOR AND CONTROLLER

"SMOKE SENTRY" rings bell and flashes red signal when inefficient combustion causes smoke. A beam of light from an "electric eye" on one side of breeching is focused on a light-sensitive cell on opposite side. With no smoke, there is no diminution of light intensity, but a small quantity of smoke affects reaction on cell. An adjustable pointer indicates density at which signals start.

Boiler Room Equipment, Inc., 45 West 45th St., New York, N. Y.

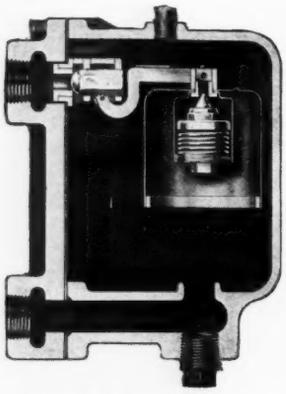



GROUND TERMINAL
GYPTOL SEAL HIGH VOLTAGE TERMINAL
HEAVY STRANDED WIRE CONNECTION TO TERMINAL
LIFT HOLE
HEAVY PLATE STEEL FOR COMPRESSION OF STACK
HEAVY WELDED HOT GALVANIZED NON-CORROSIVE STEEL CONTAINER DYKANOL FILLED
SPACE FILLED WITH DYKANOL
STEEL TENSION MEMBER
TRIPLE LAYERS OF IMPREGNATED INSULATION
CAPACITOR SECTIONS CONSISTING OF ELECTRODE FOILS SEPARATED BY LAYERS OF DIELECTRIC IMPREGNATED PAPER
NON-CONDUCTOR UPPER SECTION SUPPORT
PLUG FOR IMPREGNATING WITH DYKANOL
DOUBLE CONE TYPE INSULATOR WET PROCESS PORCELAIN

POWER-FACTOR CORRECTION CAPACITOR

EACH CAPACITOR section consists of dielectric wound of laminations of thin linen paper interspersed with two aluminum-foil electrodes. Stack is insulated from clamp and case by layers of insulation, vacuum-dried and "Dykanol"-impregnated. 5, 10 or 15 kva. with voltage ratings from 2300 to 6900 volts. Claimed to be 99.7% efficient.

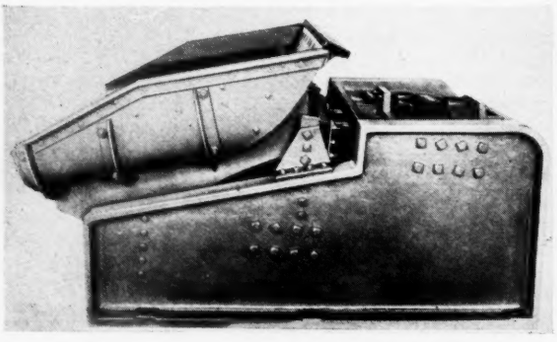
Cornell-Dubilier Corp., 4377 Bronx Blvd., New York, N. Y.

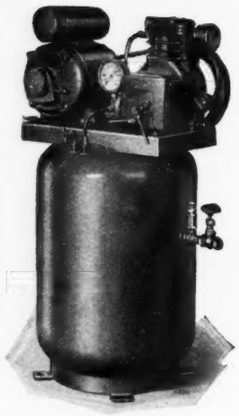


MATERIALS FEEDER

FOR COAL, ore, rock, etc., electro-magnetic feeder uses a.c. Power is received through wall-mounted rectifier, auto transformer and amplitude speed-adjusting switch. Straight-line reciprocating armature, mounted between two pole pieces splits a.c. cycle, sending half of sine wave to each pole piece. Two types, suspended or rubber-mounted on foundation.

Allis-Chalmers Mfg. Co., Milwaukee, Wis.





FRACTIONAL-HORSEPOWER AIR COMPRESSORS

MADE IN ¼- and ½-hp. sizes with automatic start and stop control, seamless steel tank, and new type check valve. For single-phase current, compressors have brushless capacitator motor and built-in, automatic protection against overload and undervoltage protection. Rated 150 lb. per sq. in maximum pressure. 2.4-cu.ft. tank for both sizes or 4.6-cu.ft. tank for ½-hp. size in either vertical or horizontal mounting.

Ingersoll-Rand Co., Phillipsburg, N. J.

BUCKET TRAP *(photo left)*

COMPLETING line of float-thermostatic traps, this unit can be furnished with integral air bypass carried inside bucket consisting of a balanced-pressure, thermostatic-trap element. Bypass said never to require setting and to operate satisfactorily regardless of pressure fluctuations. Sizes ½ to 2 in., with cast-iron bodies for 125 lb. pressure, semi-steel to 250 lb., and cast-steel up to 500 lb.

Sarco Co., Inc., 183 Madison Ave., New York, N. Y.

EMERGENCY SPRINKLER SHUT-OFF

"TEJAX" sprinkler shut-offs made in two types, one for sprinkler head with crown up and one for head with crown down. Clasping hook has specially-designed horn curved to slip into sprinkler yoke. Fitted to pole, it is operated through side lever.

Tefft-Jackson, Inc., 2 Allen Ave., Providence, R. I.

ACID NEUTRALIZER FOR FUEL OIL

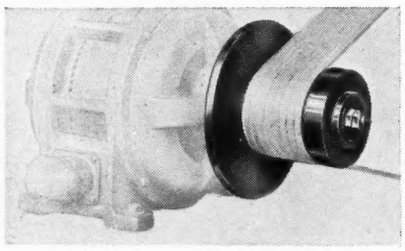
5-PLATE UNIT said to neutralize acid in fuel oil and make harmless any moisture carried in suspension. Manufacturer states that as moisture and acid in oil come in contact with plates, a battery action takes place. A small electric current is generated, and as acid eats away special alloy plates, it is neutralized. Water settles to bottom of 7x13-in. container from where it can be drained. 35,000 to 40,000 gal. of oil may be passed over plates before new ones need be installed.

Cunningham Co., 4252 Santa Monica Blvd., Los Angeles, Calif.

AUTOMATIC CLUTCH

THREE principal parts: drive plate keyed to drive shaft; movable plate, upon hub of which is keyed a pulley, sheave or sprocket—entire assembly being mounted on a quill; and floating on shaft, actuating unit equipped with time-lag adjusting mechanism and centrifugal weights which operate movable clutch plate as actuating unit comes up to speed. Size range of 1/20 to 350 hp., speed range of 600 to 3600 r.p.m. Time-lag interval adjustable to 10 min. max.

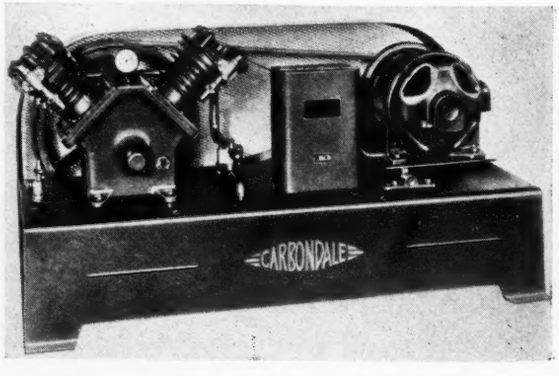
Dickson Automatic Clutch Co., 606 S. Hill St., Los Angeles, Calif.

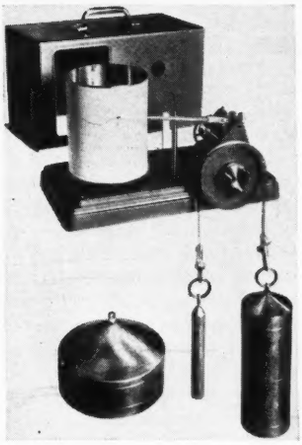


LOW-PRESSURE REFRIGERATING UNIT

FOR BOTH air-conditioning and refrigerating service, low-pressure unit employs either freon or methyl chloride as refrigerant. V-type compressor, from 4 to 8 cyl., depending on capacity, mounted on welded-steel base. Light-weight, feather-type suction and discharge valves. Multi-V electric motor drive. Welded-shell condenser with copper-finned tubing. Automatic starting, bronze bearings. Bulletin 1121.

Carbondale Div., Worthington Pump & Machinery Corp., Harrison, N. J.





WATER-LEVEL RECORDER

TWO MODELS, FW-1 and -2, first a curvilinear co-ordinate and second a rectilinear co-ordinate type. Both identical in construction except for pantograph mechanism of Model FW-1 which provides vertical pen movement. Pantograph, by introduction of added parts, increases float-wheel torque to slightly less than ½ in.-oz., making it more sensitive and accurate. Either 6- or 3-in. diameter float, temperature-compensated clock movement.

Julien P. Friez & Sons, Inc., Baltimore, Md.

BACTERIA CONTROL FOR AIR CONDITIONING

"OAKITE AIREFINER", when added to recirculating water used to wash or scrub air, is claimed to keep wash water sterile and prevent growth of slime and algae deposits. Said to be completely soluble, to transmit no odor, and to provide a stable, colorless solution that is safe and nontoxic.

Oakite Products, Inc., 22 Thames St., New York, N. Y.

MOTOR-MOUNTED PUMP

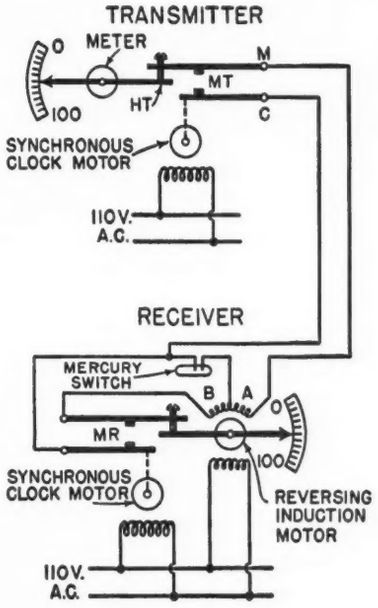
FOR CAPACITIES of 5 to 1200 g.p.m. and heads of 10 to 230 ft. Pump is mounted on end bell of electric motor, two forming self-contained unit with one shaft and two bearings. Cast-iron pump casing. Impeller, wearing ring, shaft sleeve, stuffing box gland and lantern ring of bronze. All pump parts can be removed without disturbing motor. Special materials supplied where required.

De Laval Steam Turbine Co., Trenton, N. J.

ELECTRIC FLOW METER

"SYNCHRO METER" consists of a "Ledoux" bell-flow measuring mechanism and a receiver containing indicating, recording and/or integrating instruments. Transmitter is located at point of measurement of variable and receiver at most convenient place. In diagram, contact arms of transmitter swing about points *M* and *C* and constant-speed cam swings lower contact arm in a continuous reciprocating cycle. Upper arm is positioned through stop *HT*. Receiver operates in a similar manner, except that upper contact arm is positioned by reversing induction motor. For 95 to 125 volts a.c., 25, 50 or 60 cycles.

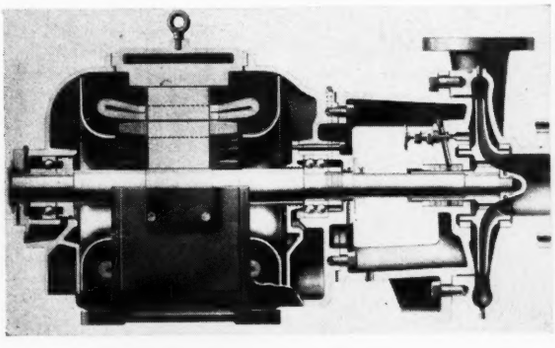
Bailey Meter Co., Cleveland, Ohio.

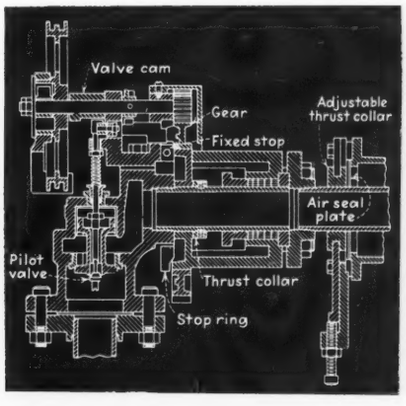


SOOT BLOWER

AUTOMATIC valve-operating mechanism is adjusted to open and remain open during blowing arc as soon as blower element has come into proper position. Valve housing can be removed without disconnecting head from element. Short pipe connections said to practically eliminate condensation and automatic air-check valves prevent acid formation and corrosion of parts. Single chain, when pulled in one direction, opens valve; and when pulled in opposite direction, rotates element.

The Bayer Co., 4067 Park Ave., St. Louis, Mo.





VIBRATING-REED TACHOMETER

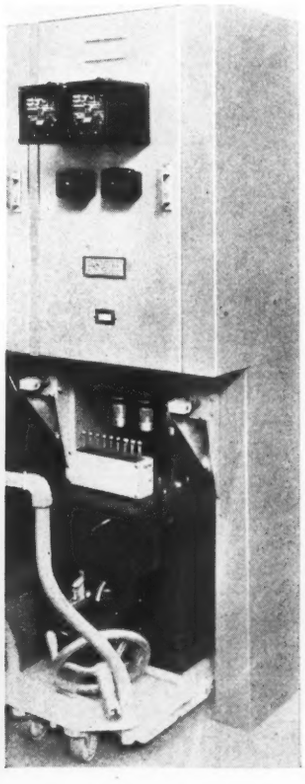
FOR MEASURING rotational or r.p.m. speeds of motors, turbines, spindles, shafting, and vibrations per min. of pneumatic hammers and drills. "Frahm" tachometers record speeds up to 30,000 r.p.m. Illustrated is hand type which records when held against some stationary part of machine.

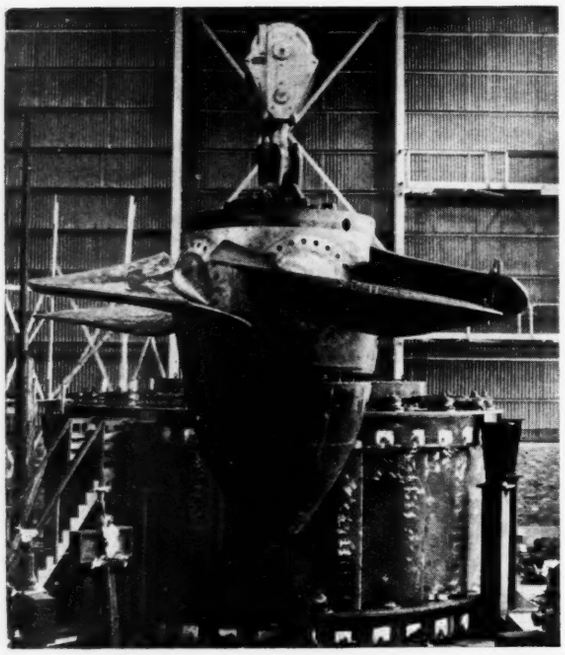
James G. Biddle Co., 1211-33 Arch St., Philadelphia, Pa.

METAL-CLAD SWITCHGEAR

ILLUSTRATED is 50,000-kva. switchgear in which oil circuit breaker has been lowered by handwheel to truck and is ready for removal. Lifting and lowering device in stationary element is self-contained mechanism which automatically places circuit breaker in correct position to engage primary and secondary disconnectors. Breaker may be raised or lowered by hand or with portable motor.

Delta-Star Electric Co., 2400 Fulton St., Chicago, Ill.





RUNNER UP IN THE AIR

Kaplan runner suspended from a crane block in the S. Morgan Smith shops where two turbines, each rated 66,000 hp. at 50-ft. head, are being built for Bonneville development on the Columbia River, near Portland, Ore. The runner assembly shown weighs approximately 275,000 lb. and is 23 ft., 4 in. in diameter. At full load each unit will pass 12,000 cu.ft. of water per second

POWER LINES

Three New Turbines For Delray No. 3

For the next few years, Detroit Edison's Delray Power House No. 3 will be the scene of much activity. Extensions to present buildings for housing three 75,000-kw. turbo-generators and six new boilers have been authorized and a seventh boiler will be installed in available space in the present building. When completed, this station will have 375,000 kw. of main turbo-generator capacity.

New boilers will be mounted on large, water-cooled furnaces about 65 ft. tall with 23x26-ft. floor area. Steel columns which support the furnace and boiler will inclose a floor space 30 ft. square.

Stokers for the new boilers, essentially the same as those under present boilers, are being supplied by American Engineering Co. (which is also furnishing 3 Taylor stokers for the Detroit Edison Conners Creek station).

Steam will be extracted from turbines at four points for heating boiler feedwater. Condensers will be served by single 67,000-g.p.m. circulators, which will require 400 hp. each.

Riverside Addition Begun

Work started April 9 on installation of a 35,000-kw. electric generating unit and two additional boilers at Riverside steam station of Minneapolis General Electric Co. Present capacity of this station, the largest electric generating station in the Central Northwest, is 107,000 kw. When the new generating unit is completed, total capacity will be 142,000 kw.

Springdale Protected For 30.5-ft. Flood Rise

By raising vital generator leads, constructing bulkheads for all openings, closing other openings not vitally necessary, and strengthening parts of structures not capable of withstanding hydrostatic pressure at flood height, Springdale power plant, Springdale, Pa. (near Pittsburgh) has been made less vulnerable to floods. With these alterations, the river may reach a stage of 30.5 ft. above normal before generating equipment will have to be shut down. As an additional precaution, five sump pumps with a total capacity of 20,000 g.p.m. have been installed to take care of seepage.

Originally the power station was designed to be safe from flood to the height of the turbine-room floor, 6.7 ft. above previous high water. Present changes will provide safety to a point 6 ft. higher. The St. Patrick's Day flood, March, 1936, rose 1.7 ft. above the floor.

Generator leads of units 3, 4 and 5 were originally under the walkway beneath the main building and switch house. These have been replaced with new leads high above flood stage by carrying them up inside of the turbine-room wall and overhead from there to the switch house. All door openings have been provided with steel bulkheads which may be bolted to bars anchored in the concrete wall and provided with felt gaskets to make them water-tight. Each bulkhead is marked and stored as near as possible to the opening it will seal.

All basement windows were permanently closed with reinforced concrete diaphragms, and all pipe openings through outer walls were sealed with gaskets. Concrete walls of areaways around air intakes for generators 3, 4 and 5 were built up with reinforced concrete equivalent to a 30.5-ft. rise.

The basement floor in the southwest corner of the main building was found too weak to resist the increased pressure of a 30.5-ft. flood rise. This room has been isolated with bulkheads from the remainder of the plant and is provided with a control valve to permit flood water to enter to a predetermined height sufficient to counterbalance that part of the upward pressure which cannot be resisted by the floor itself.

130,000 Kw. Capacity Planned for Four States

Announcement of new plants and additions came fast and thick as 1937 brought increased demands on existing power facilities. In addition to the Commonwealth & Southern expansion program, utilities in Massachusetts, Indiana, Virginia and Tennessee have begun preliminary plans or have started construction on new plants or extension totalling 130,000 kw.

Public Service Co. of Indiana recently filed petitions with the Indiana Public Service Commission, in which it announced plans for a $4,755,000 generating station at Dresser. The plant, to have a proposed capacity of 50,000 kw., will be designed and built to be operated as part of the existing station and will serve central, southern and southwestern Indiana. Company officials estimated 18 months will be required to build the new unit. Work will be started as soon as Commission approval is given.

The first major increase in generating capacity for Boston Edison was put under way this month as construction began on installation of a 25,000-kw. Westinghouse turbo-generator for L Street station. The "topping" turbo-generator is designed for 1,250 lb. Two 300,000-lb. per hr. Combustion Engineering pulverized-coal fired boilers will operate at drum pressure of 1,400 lb. per sq.in.

A $3,000,000 addition to the Cumberland River plant of Potomac Edison Co. is already under way. The unit will have a 30,000-kw. GE turbo-generator and a 825-lb. boiler capable of producing 312,000 lb. of steam per hr. Company officials expect to put the addition into operation in December, 1938.

Tennessee Electric Power Co. has applied to the Tennessee Railroad & Public Utilities Commission for permission to build a $2,000,000 steam-electric plant on the Cumberland River. Proposed capacity is 25,000 kw.

Prime-Mover Control Meeting

Woodward Governor Co., Rockford, Ill., will hold its 8th Annual Prime Mover Control Conference June 1-5 in Rockford. The 5-day program will include discussion and instruction on con-

struction, operation and maintenance of single-valve and relay-valve governors, isochronous governors for stationary a.c. steam and internal-combustion prime movers, and relay-valve governors and actuators in hydroelectric service.

Commonwealth & Southern Orders Eight Turbines

Increased capacity for six Commonwealth & Southern system companies in Indiana, Ohio, Michigan and Pennsylvania was announced recently when orders were placed for eight turbines. All are designed to operate under identical steam conditions and all are for condensing operations.

Consumers Power Co. has three projects under way, two new plants. Construction work has been started on the John C. Weadock plant at Bay City, Mich. Two 35,000-kw., 80% power factor, hydrogen-cooled, 800-lb., 850-F turbo-generators will be supplied by boilers rated at 900 lb. and 900 F maximum.

The new plant in southern Michigan, on the Kalamazoo River, will be named for Bryce E. Morrow, who at the time of his death over a year ago was chief engineer and manager of the production and transmission department of Consumers Power. The initial installation will consist of a 35,000-kw. turbine and boiler identical with one of the John C. Weadock units.

In addition, Consumers Power is expanding its Elm Street station at Battle Creek, where an 800-lb. boiler and a 10,000-kw., 3,600-r.p.m. superposed turbo-generator will increase capacity to 50,000 kw.

Southern Indiana Gas & Electric is expanding its Ohio River station at Evansville with the addition of an 800-lb., 850-F steam turbine driving a 20,000-kw. air-cooled generator. A pulverized-fuel fired boiler will supply steam.

An extension to the East Peoria plant of Central Illinois Light Co. is under construction, and involves the addition of a pulverized-fuel steam boiler and a 25,000-kw. turbo-generator.

For its Mad River plant, Ohio Edison has ordered a 20,000-kw., 3,600-r.p.m. turbo-generator and a pulverized-fuel fired boiler. Pennsylvania Power Co. will have a 35,000-kw., hydrogen-cooled turbo-generating unit, similar to the Bay City Weadock installation. This unit will be installed on a new site at New Castle, Pa.

Peru Requests Catalogs

The Consul of Peru in Philadelphia advises that his government has requested him to obtain for the Industrial Bank of Peru catalogs, price lists, etc., on industrial equipment. The bank has been organized to foster modernization of existing industry in Peru and to help new industry establish itself. Catalogs, price lists and other data may be sent in duplicate to Federico Elguera, Consul of Peru, 2314 Locust St., Philadelphia, Pa.

General Motors Announces Diesel Engine Division

General Motors Corp. began erection last month of an engineering laboratory for its recently announced Diesel Engine Division which will be headed by William T. Crowe, formerly on the staff of O. E. Hunt, vice-president of General Motors in charge of engineering.

W. T. Crowe

The new division will manufacture a line of Winton diesels, beginning with a 20-hp., single-cyl. unit up to a 160-hp., 6-cyl. engine. Single-cyl. engines will be designed for stationary use only, whereas multi-cyl. engines will be adaptable to marine, stationary or commercial-vehicle use. The manufacture of diesel-engine fuel injectors, carried on in the General Motors Research Laboratories for the past several years, will be moved to the new plant as soon as possible.

Boiler Inspectors Meet

National Board of Boiler and Pressure Vessel Inspectors met for its 11th General Meeting at the Hotel McAlpin, May 24-26, in New York City. A partial list of subjects discussed includes: welding problems in connection with high tensile strength low-alloy steel, use of non-ferrous and ferrous alloys in the construction of pressure vessels, latest developments of steam generating plants, design and testing of safety valves, welding of power-plant piping, development of forced-circulation boilers, avoidance of furnace explosions, and safe operation of low-pressure steam boilers and hot-water vessels.

A special exhibit showed examples of sound and defective welding, of failures experienced in operation, and of new construction and design of boilers.

Third 110,000-kw. Turbine For River Rouge Plant

Ford Motor Co. has ordered a third 110,000-kw., hydrogen-cooled turbo-generator from General Electric Co. for its River Rouge plant. The addition will increase by 50% the installed capacity in large 1,200-lb. steam turbines. The new vertical-compound turbine will be a duplicate of the second 100,000-kw. unit, recently installed, for steam conditions of 1,200 lb., 900 F and 1-in. back pressure. The 1,800-r.p.m. high-pressure turbine and generator are mounted on top of the 1,800-r.p.m, double-flow, low-pressure unit.

A high-pressure boiler unit, capable of delivering 900,000 lb. of steam per hr., will be furnished by Combustion Engineering Co.

"Dry Ice" from Flue Gas Described at A.Ch.S. Meeting

A chemical process promising to make every smoking factory chimney in America a potential commercial source of "dry ice" was described at the 93rd annual meeting of the American Chemical Society held at Chapel Hill, N. C., in April.

The new method, which utilizes ammonia gas to speed up chemical reactions in giant absorption towers where flue gas is passed through a lye solution, permits substantial recovery of CO_2 of which "dry ice" is the solid form, from flue gas of relatively low carbon-dioxide content. Hitherto, CO_2 could be economically obtained only as a byproduct.

Devised by Prof. R. H. McKee of Columbia University and E. A. Winter,

HIGH WATER AT RICHMOND, VA.

APRIL SHOWERS brought high waters to Richmond, Va. Water in the James River rushes past Belle Isle hydro station (shown partly submerged in the center of the picture), part of the Virginia Electric & Power Co. system—*Wide World Photo*

research student at Columbia, the new absorption process consists of combining CO_2 in the flue gas with ammonia in the presence of water vapor. By establishing an excess of ammonia in even a very short section of tower, virtually all CO_2 can be forced to react.

Ordinary absorption towers are packed with coke, down which lye trickles concurrent to the flow of flue gas, but experience has shown that steel turnings sifted free of particles under ¼-in. are superior. In practice, ammonia present in the gas phase in the tower apparently acts in the manner of catalyst in carrying CO_2 into the lye solution. As ammonium carbonate is formed, it is dissolved into the lye, whose alkalinity decomposes the carbonate and frees ammonia to re-enter the vapor-phase reaction zone. This cyclic process continuously repeats itself. CO_2 is then boiled off from the charged lye.

New Jersey Strengthens Pressure-Vessel Code

New Jersey, aiming at greater safety, recently issued an order through the Commissioner of Labor, John J. Toohey, Jr., requiring that all air and other pressure vessels to be used in New Jersey must be constructed to meet all state constructional specifications. The order also specifies that before vessels leave the shop where they are built, they must be stamped New Jersey Standard, A.S.M.E. Standard, or National Board Standard by a certified shop inspector, who is an employee of the State of New Jersey or an employee of an insurance company authorized to inspect such apparatus for that state.

The Commissioner also issued an order embracing a survey of all industrial plants in the state using unfired pressure vessels. The purpose of the survey is to ascertain the number and type of vessels being used in the state, and to determine whether or not they are properly constructed and equipped for safe operation.

Sinclair to Receive Longstreth Medal

Harold Sinclair, managing director of Hydraulic Coupling & Engineering Co., Ltd., Isleworth, England, arrived in New York May 3 to receive the Edward Longstreth medal awarded by the Franklin Institute for his work in the adaptation of the Föttinger hydraulic coupling to variable-speed drives in industry. A further objective of his visit is to interchange experience concerning general industrial, rail and road traction applications of the Vulcan Sinclair fluid coupling with the Hydraulic Coupling Division of American Blower Corp.

Mr. Sinclair has been actively engaged since 1928 in the development of the fluid coupling from the original form in which it was produced for marine propulsion by Vulcan-Werk of Hamburg, Germany. The first prominent success of this coupling was its adoption by

Harold Sinclair

Daimler Co. of England for motor-car and city-bus transmissions under the name "Fluid Flywheel." The coupling has also found major use as an automatic "clutch" for a variety of drives and as non-stalling feature for squirrel-cage motor drives to conveyors, etc.

PERSONALS

DONALD MCCORMICK, formerly welding supervisor for Sheffield Steel Co., has been appointed welding consultant for Lincoln Electric Co.'s office in Kansas City, Mo.

EDWARD L. BOHN, formerly with American Refractories Co., is now associated with Charles Taylor Sons Co., Cincinnati, as sales manager of the Fire Clay Refractories Div.

C. E. SULLIVAN was recently appointed vice-president of The Foxboro Co., Foxboro, Mass. Mr. Sullivan has been affiliated with Foxboro for 26 years and has been sales manager since 1920.

D. J. HENECKER has been appointed manager of Wire Rope Sales Dept. of Wickwire Spencer Steel Co., succeeding R. H. Cherry, recently deceased. F. P. Clark has been appointed to fill Mr. Henecker's former position as Buffalo district sales manager.

WILLIAM K. CLOW, JR., formerly general manager of Henszey Co., Watertown, Wis., has joined Elgin Softener Corp.'s technical staff. Mr. Clow will specialize in boiler-water conditioning.

I. D. APPLEGATE has been placed in charge of engineering, design and development of automatic voltage, current and speed regulators for Ideal Commutator Dresser Co., Sycamore, Ill. Mr. Applegate was formerly with Westinghouse Electric & Mfg. Co.

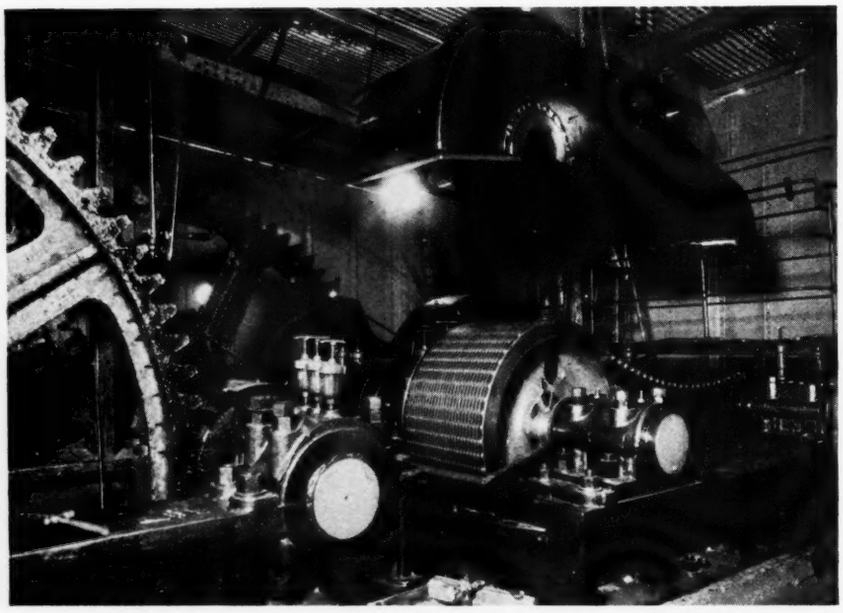
ALFRED IDDLES has become associated with Babcock & Wilcox Co.'s Engineering Dept., and will have charge of application engineering and service work. Until recently, Mr. Iddles was executive vice-president of United Engineers & Constructors, Inc., Philadelphia.

WADE H. BURLESON, former assistant manager of the Power Utilities Dept. of Ohio Brass Co., Mansfield, Ohio, has been appointed manager of that department, succeeding M. M. Kenneally, resigned.

H. G. MEISSNER, for the past 15 years engaged in combustion engineering work with Illinois Stoker Co., Riley Stoker

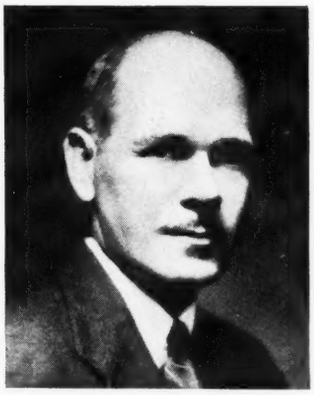
CHAIN DRIVE FOR MARINE WAYS

THIS LINK-BELT silent-chain drive connects an 800-hp., 300-r.p.m. motor to the gear shaft of a shipyard marine-ways hoisting machine. The motor pinion with a 16.77-in. pitch diameter and 21 teeth is connected to a drive wheel having a pitch diameter of 40.61 in. and 51 teeth. The chain is 30 in. wide, operates on 6 ft., 1.5 in. center distance, is totally enclosed and automatically lubricated



Corp., and Consolidation Coal Co., is now a field engineer with Combustion Engineering Co.

JAMES E. WATSON, executive vice-president of Elliott Co., Jeanette, Pa., has been elected president to succeed G. F. Elliott, who has been president since



the death of his father, W. S. Elliott, founder of the company, who died in 1935. Mr. Watson joined Elliott Co. immediately after his graduation from Penn State College in 1911, and has been the organization's executive vice-president since 1920.

W. G. HEACOCK, a member of Air-Maze Corp. organization since 1928, has been appointed Michigan factory representative with headquarters at 2832 East Grand Blvd., Detroit, Mich.

EDGAR S. DAUGHERTY has been made head of Heater Div. of the Water Conditioning and Purification Dept. for Cochrane Corp., Philadelphia. Mr. Daugherty has been with Cochrane since 1923, and since 1928 has specialized in feedwater deaeration, first as technical engineer, then in a sales-engineering capacity.

M. E. CLARK has been appointed sales manager of Randall Graphite Products Corp., Chicago. Mr. Clark was formerly associated with Bunting Brass & Bronze Co. and Drying Systems, Inc.

OBITUARIES

OZRO F. KEITH, 69, former power superintendent for Moran Mfg. Co., Providence, R. I., died at his home in Pawtucket, R. I., April 26.

GEORGE H. PETERSON, 65, for many years with Boston Edison Co.'s generating department and at one time a steam operating engineer at the Woburn station of the predecessor utility in Boston, died recently.

WILLIAM RICHMOND, 76, formerly plant engineer with Arlington, Mass., Town Laundry, died suddenly in Arlington April 15.

JAMES MERCER, 84, chief engineer of Ivers & Pond Piano factories in Watertown and Boston for 36 years, died at his home in Hanover, Mass., April 14.

CHARLES H. SIAS, 48, formerly engineer at McLean Hospital in Waverly, Mass., and during the World War with the U. S. Army in Fort Terry, N. Y. nitrate plant, died in Boston, April 4.

COL. JOHN SPENCER, 76, inventor of the Spencer damper regulator and a holder of a John Scott medal for meritorious inventions died at the Salem, Mass. Hospital March 31.

NICHOLAS F. KEPPLE, chief engineer of the Massachusetts State Farm at Bridgewater, was instantly killed April 29 by the bursting of a gasoline tank which was being tested for leaks by steam pressure. Mr. Kepple was a lifelong resident of Fall River, Mass., and had previousy been engineer at Fall River General Hospital and Border City Mfg. Co. plants.

DR. O. P. HOOD, until last year chief mechanical engineer of the U. S. Bureau of Mines, died recently at his home in Washington, D. C. Dr. Hood joined the Bureau of Mines at its Pittsburgh Experiment Station in 1911. He assumed charge of fuel investigation and developed mechanical and electrical research pertaining to safety in mines. The Davis multiple-unit calorimeter, the Burrell gas detector, and the Gibbs oxygen breathing apparatus are early examples of his mechanical genius. He directed smoke-abatement investigations in a number of cities, carried out nation-wide sampling of coal and its analysis, and made substantial savings of heat and power in Government plants. Dr. Hood was a member of the A.S.M.E., A.I.M.M.E., A.S.H.V.E., and Int. R. R. Fuel Assn.

BUSINESS ITEMS

AMERICAN ENGINEERING CO., Philadelphia, has appointed the following representatives to handle "Lo-Hed" electric hoists: James B. Barton, Jr., Atlanta, Ga.; G. R. Douglas, Memphis, Tenn.; F. E. Bennett, Portland, Ore.; Murray-Jacobs Co., Seattle, Wash.; F. H. Hill, Chicago; C. G. Forshey, Houston, Tex.; L. E. Kenney, New Orleans; E. V. Brown, San Francisco; Hart Machinery Co., Tampa, Fla.; and Peter H. H. Dunn, Washington, D. C.

PITTSBURGH STEEL CO. has accepted resignation of E. W. Smith as general sales manager. W. G. Hume continues as manager of sales for wire products and C. V. Lally as manager of sales for seamless-steel tubes. The office of general manager of sales will remain vacant.

COMMERCIAL TESTING & ENGRG. CO., Chicago, has moved its offices to larger quarters at 307 N. Michigan Ave. Laboratories have also been moved to 225 N. Michigan Ave.

HOMESTEAD VALVE MFG. CO., Coraopolis, Pa., announces appointment of the following distributors for chemical vapor-spray cleaning machines: Toledo Equipt. & Supply Co., Toledo, Ohio; Oil Burner Equipt. Co., Tampa, Fla.; Merkel & Roberts, Painesville, Ohio; and Gleasner Corp., Buffalo, N. Y.

ALLIS-CHALMERS MFG. CO., Milwaukee, has opened an office at 211 N. Champion St., Youngstown, Ohio. C. H. Legler will have charge of the new office, which will operate as a branch of the Pittsburgh district office.

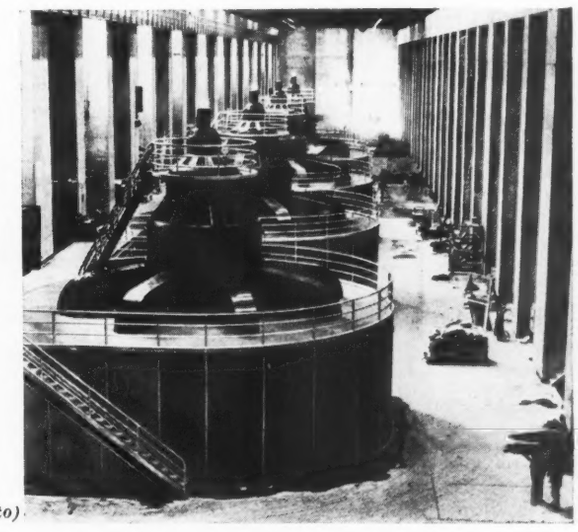
GENERAL REFRACTORIES CO., Philadelphia, at a meeting of the board of directors held in mid-April, elected S. M. D. Clapper, formerly president, chairman of the board. Floyd L. Greener, formerly executive vice-president, was elected president.

INTERNATIONAL BOILER WORKS CO., East Stroudsburg, Pa., has announced that Ernest H. Taylor is now vice-president in charge of production and will henceforth have complete charge of the East Stroudsburg factory. John B. Kingsley is now vice-president in charge of sales and will be at the New York sales office, 101 Park Ave., New York, N. Y.

BLACKMER PUMP CO., Grand Rapids, Mich., announces appointment of G. H. Burke of Burke Engineering Co., Kan-

BOULDER GENERATORS

Interior view of the Boulder Dam power house showing the initial installation of generating equipment. Four 82,500-kva. generators have been installed in the Nevada wing of the huge L-shaped station, and are now in service on the line serving Los Angeles



(Acme Photo)

sas City, Mo., as representative for western Missouri and Kansas.

HOMESTEAD VALVE MFG. CO., Coraopolis, Pa., has appointed following representatives for quarter-turn plug valves and boiler blow-off valves: Warren Bruce & Co., St. Louis and Proctor Engrg. Co., Inc., Baltimore.

GENERAL MACHINERY CORP., Hamilton, Ohio, recently elected J. E. Peterson vice-president and assistant to the president. At the same time, its subsidiary, Hooven, Owens, Rentschler Co., elected Frederick Ritz vice-president in charge of diesel-engine manufacturing.

L. HERES DE WYK & SON, consulting engineers, Ansonia, Conn., have been appointed sales representatives for A. B. Farquhart Co., Ltd.

BLAW-KNOX CO., Pittsburgh, Pa., has acquired property and business of Power Piping Co. of Pittsburgh. The business will be operated under the name of Power Piping Corp.

LINCOLN ELECTRIC CO., Cleveland, Ohio, has appointed William Sivyer and B. B. Ross to the sales staff of its Philadelphia office, 401 N. Broad St.

HOFFMAN COMBUSTION ENGRG. CO. has moved its Detroit office to the Marquette Bldg., 243 W. Congress St.

MEETINGS

American Institute of Electrical Engineers —*Annual Summer Convention, June 21–25, Milwaukee, Wis. H. H. Henline, national secretary, 33 W. 39th St., New York, N. Y.*

American Society for Testing Materials—*Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y., June 28–July 2. R. E. Hess, assistant secretary, 260 South Broad St., Philadelphia, Pa.*

American Society of Heating & Ventilating Engineers—*Semi-Annual Meeting, Swampscott, Mass., June 24-26. A. V. Hutchinson, secretary, 51 Madison Ave., New York, N. Y.*

Canadian Electrical Association — *Annual Convention, June 21–24, Banff Springs Hotel, Banff, Alberta, B. C. Fairchild, secretary, 804 Tramways Bldg., Montreal, Quebec.*

Chicago Exposition of Power & Mechanical Engineering, *International Ampitheatre, Chicago, Ill., Oct. 4–9. Address Charles F. Roth, vice-president of International Exposition Co., Grand Central Palace, New York, N. Y.*

Economic Conference for Engineers — *Seventh Annual Meeting, Stevens Institute of Technology Engineering Camp, Johnsonburg, N. J., June 18–26.*

National Association of Power Engineers—*Mississippi Valley Mechanical & Electrical Show, Aug. 30 to Sept. 3, Jefferson Hotel, St. Louis, Mo. Fred C. Laufketter, chairman of Executive Committee, N. A. P. E., in charge.*

Smoke Prevention Association—*31st Annual Convention, June 1-4, Hotel Pennsylvania, New York, N. Y. Session on June 2 will be held at Stevens Institute of Technology, Hoboken, N. J.*

Stoker Manufacturers Association — *Annual Meeting, White Sulphur Springs, W. Va., June 3–5.*

Universal Craftman Council of Engineers—*35th Annual Convention, Aug. 3–7, Stevens Hotel, Chicago, Ill. Exhibition of power equipment by 150 manufacturers in conjunction with convention. D. W. Haering, 3408 W. Monroe St., Chicago, Ill.*

SOCIETIES AND SCHOOLS

AMERICAN WELDING SOCIETY, 33 West 39th St., New York, N. Y., has appointed Warner S. Hays as managing director. Mr. Hays is a past president of American Trade Association Executives.

NATIONAL DISTRICT HEATING ASSOCIATION held its 28th Annual Convention in Detroit, May 25-28 in the Book Cadillac Hotel. A report of steam engineering sessions will appear in July *Power*.

THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION has announced an intensive 2-day program for its Summer Conference on the Teaching of Mechanical Engineering in Cambridge, Mass., June 28-29. M.I.T. and Harvard will be hosts. Prof. F. L. Eidman, professor of mechanical engineering at Columbia University, is chairman.

THE A.S.M.E. Semi-Annual Meeting, held at the Statler Hotel, Detroit, Mich., May 17-21, will be reported in July *Power*, with abstracts from papers presented at the power, fuels and lubrication sessions.

STRAWS

Pointing the way business winds blow

ALABAMA —— Clarke - Washington Electric Membership Assn., Salitpa, plans early construction of steam-electric generating station for rural electrification. Cost about $30,000. Financing through Federal aid.

R. V. Ellis, RD No. 1, Center, Cherokee County, heads project to construct and operate a local steam-electric generating plant for rural electric supply in Cherokee and DeKalb Counties. Cost over $100,000. Earl Solomon, county agent, Center, active in project.

CALIFORNIA —— Fox West Coast Theaters Corp., 1609 W. Washington Blvd., Los Angeles, plans boiler plant for heating motion-picture theater on Long Beach Blvd., South Gate, near Los Angeles, for which bids will be asked soon. Cost about $150,000. S. C. Lee, 381 Bush St., San Francisco, architect.

Seaboard Lemon Assn., Oxnard, plans central heating system for processing service and complete air-conditioning system in 3-story packing and storage plant. Work scheduled to begin in June. Cost about $150,000. W. W. Ache, 301 North Citrus Ave., Los Angeles, architect.

Del Mar Canning Co., 756 Ocean View, Monterey, plans boiler house at new local fruit canning and packing plant. Cost about $240,000. Morris Matheson, 782 Gibson St., Pacific Grove, in charge of construction.

DELAWARE——Seaford Power & Light Co., Seaford, recently organized subsidiary of Fairbanks, Morse & Co., Chicago, Ill., will begin work soon on new diesel-driven generating station and distributing system. Project is scheduled for completion in September. Cost close to $200,000.

FLORIDA——Ralph O. Dulany & Son, Fruitland, plan cold-storage and refrigerating plant at Jacksonville. Cost close to $40,000, with equipment.

GEORGIA——Sandersville has authorized extensions in municipal electric plant, including 380-hp. diesel and generator.

ILLINOIS——United States Treasury Dept. plans boiler plant for central heating in new 2- and 3-story garage and service building for Post Office at Canal, Clinton and Polk Sts., Chicago. Bids will be asked soon on general erection. Cost over $2,000,000.

INDIANA——Board of County Commissioners, Brazil, plans purchase of stokers for power plants at Court House and other county buildings. Appropriation will be arranged soon. Fort Wayne plans extensions in steam department of municipal electric station. Watertube boiler and auxiliary equipment to be installed. Fund of $100,000 authorized. Froehlich & Emery Eng. Co., Second National Bank Bldg., Toledo, Ohio, consulting engineers.

Board of County Commissioners, Greencastle, plans central heating plant at county hospital. Fund of about $160,000 is being arranged for this and other construction.

IOWA——Hopkinton has asked bids for electric plant and distribution system, to include two diesel-generator units and accessories. A. S. Harrington, Baum Bldg., Omaha, Neb., consulting engineer. Estimated cost $68,000.

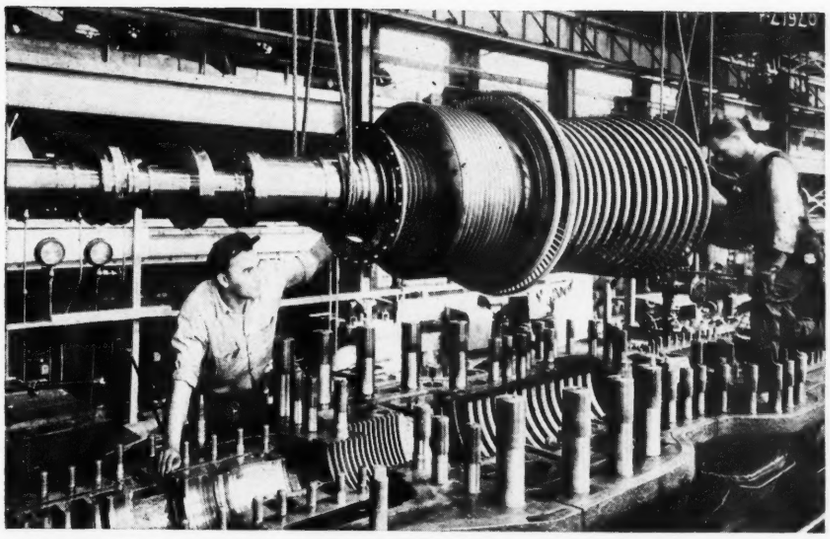
State Board of Control, Des Moines, plans power plant at institution at Fort Madison, Iowa, and proposes appropriation of $170,000 for equipment. E. H. Felton is chairman.

Central Electric Federated Co-operative Association, Pocahontas, has asked bids for diesel-generator for rural electrification system. Fund of $185,000 arranged. Young & Stanley, Muscatine, consulting engineers.

Bellevue has asked bids for improvements in municipal power plant, including 500-hp. diesel and generator.

Federated Co-operative Power Association, Iowa Falls, has asked bids for proposed electric plant near Hampton for rural electric system, to include three diesel-generators and auxiliaries. Cost about $225,000. Young & Stanley, Muscatine, consulting engineers.

KANSAS——Paola has approved bond issue of $225,000 for new municipal



49,500-KW. WATERSIDE TURBINE ABUILDING

LOWERING the rotor into the cylinder of the main 49,500-kw. turbine which is being built in the Westinghouse South Philadelphia works for the Waterside station of Consolidated Edison Co., New York City. The complete unit consists of two turbines in tandem driving a single, 53,000-kw., hydrogen-cooled generator

electric plant and distribution system. Proposed to begin work immediately. W. B. Rollins & Co., Railway Exchange Bldg., Kansas City, Mo., consulting engineers.

Hill Packing Co., foot of Jefferson St., Topeka, plans steam power house for service at food-products packing plant. Cost close to $40,000. B. W. Friedel, company architect and engineer.

Russell plans large pumping plant and main pipeline from Smoky Hill River water source to Fossil Creek Reservoir, with a second main supply line from Smoky Hill River to Big Creek dam. Bond issue of $127,700 authorized for this and other improvements. Black & Veatch, 4706 Broadway, Kansas City, Mo., consulting engineers.

KENTUCKY——Georgetown is considering municipal electric plant. Surveys and estimates of cost will be made soon. Finance and Improvements Committee of City Council in charge.

Versailles plans early purchase of diesel-driven pumping unit and accessories for waterworks station, now in course of construction. H. K. Bell, McClelland Bldg., Lexington, consulting engineer.

LOUISIANA——WPA Regional Office, Baton Rouge, plans purchase of pumping machinery and auxiliary equipment for sewage service at Independence.

MARYLAND——Celanese Corp., Amcelle, near Cumberland, has arranged with Potomac Edison Co., Hagerstown, Md., for 10,000-kw. turbo-generator in power plant at rayon mill.

MASSACHUSETTS——New England Coal & Coke Co., 250 Stuart St., Boston, plans coal-hoisting tower and mechanical-handling facilities on Water St., Beverly. G. P. Carver Eng. Co., 214 State St., Boston, engineer.

New England Medical Center, 25 Bennet St., Boston, plans central heating plant in new 6-story and basement hospital. Cost about $450,000. Coolidge & Carlson, 89 State St., architects.

MICHIGAN——Company now being organized to manufacture gypsum products, represented by Eugene D. Kirkby, 1928 Buhl Bldg., Detroit, plans power house at new multi-unit plant near Turner, Arenac County. Cost close to $800,000. Work scheduled soon.

Lenawee County Rural Electric Co-Operative, Inc., Adrian, plans steam-electric generating plant for rural electric supply. $630,000 through Federal aid. E. Cyril Bevan, National Bank Bldg., Detroit, attorney and representative.

Gladstone plans extensions in municipal electric plant. Cost close to $100,000.

NORTH DAKOTA——State engineer, D. W. Loucko, Pierre, is preparing plans for purchase and installation of $15,000 turbo-generator for State Sanitorium at Custer.

Walhalla is arranging a bond issue of $58,000 for new municipal electric plant. Proposed to begin work soon. E. L. Lium, 913 Almonte St., Grand Forks, consulting engineer.

OHIO——Glouster is considering construction of a municipal electric plant. Estimates of cost will be made soon.

Chevrolet Motor Co., Inc., 4726 Smith Rd., Cincinnati, will make extensions in power plant at local automobile works. Cost about $250,000.

Delphos will vote June 22 on a $300,000 bond issue for construction of a municipal electric plant.

Reading plans improvements in municipal electric plant to include steam turbo-generator unit and auxiliaries. New concrete stack will be built. Proposed to ask bids soon. Carl J. Kiefer Associates, Inc., Schmidt Bldg., Cincinnati, consulting engineers. Philip Bok, director, Department of Public Service, in charge.

SOUTH DAKOTA——Beresford has asked bids for improvements in municipal electric plant, to include 500-hp. diesel and generator, exciter and auxiliary equipment. J. M. Engberg, Madison, consulting engineer.

Parker plans improvements in municipal electric plant, including generator and auxiliary equipment.

TEXAS——Channel Gas Co., Houston, plans welded-steel pipeline from Dickinson to Houston, about 30 miles, for natural-gas transmission. Booster stations will be built. Cost over $250,000.

Humble Pipe Line Co., Humble Building, Houston, plans 6-in. welded-steel pipeline from oil-field district at North Cowden to Andrews. Cost over $100,000.

Bryan plans central heating plant in new high school. Expect to ask bids on general contract in August. Cost about $325,000. Giesecke & Harris, 207 West Seventh Ave., Austin, architects.

Landreth Production Corp., Petroleum Bldg., Fort Worth, E. A. Landreth, president, plans installation of engines and compressor units in proposed natural gasoline plant in Aransas County. Welded-steel pipeline system will be built for gas to plant. Cost over $400,000.

VIRGINIA——Waverly plans municipal electric plant. Cost about $91,000. Financing through Federal aid.

Blackstone plans extensions in municipal electric station, including 800-hp. diesel and generator. Fund of about $60,000 being arranged.

Galax has preliminary plans for a municipal electric plant. Cost about $237,000. Federal financing.

WASHINGTON——Bellingham plans pumping machinery and auxiliary equipment, pipe lines and other facilities for extensions in water-supply system. Bond issue of $1,000,000 is being arranged.

Washington Packers, Inc., Puyallup, plans installation of cold storage and refrigerating division in canning and packing plant. Cost about $65,000. O. E. Shay, acting manager.

WISCONSIN——Pardeeville Electric Light Co., Pardeeville, plans early rebuilding of power plant, recently damaged by fire. No estimate of loss announced.

ALASKA——Seward closes bids June 7 for new municipal electric station, including diesel-generating units and accessories. Fund of $90,000 arranged for plant and distribution lines.

TO WATER . . .

"Johnny," said the teacher, "if you have seventeen sheep in a pasture and one jumps the fence, how many are left?" Johnny, a typical farmer kid, didn't hesitate a second. "None," he said. "But, Johnny," she persisted, "you know that $17 - 1 = 16$." "Teacher," said Johnny, "you may know mathematics, but you sure don't know sheep!"

It is with such stories that we are all taught as youngsters to go our own way, getting still more encouragement from the old saw, "You can lead a horse to water, but you can't make him drink." On such ideals is American individuality based.

As a matter of fact, the much-despised mule has a lot more horse-sense than a horse has. If a horse decides to get you off his back, he'll stop at nothing, even if he hurts himself. He'll run into a wall, smash into a tree, or jump off a cliff. A mule won't. He'll try to scrape you off under a limb or swing you off by a sharp turn, but he's careful of his own hide.

What I'm suggesting is that we might get a little mule-sense—a little ability to think sensibly for ourselves, not pattern after either the sheep or the horse. Before the depression, June and July were good months to fix up the plant, because load was low due to slack demand, no heating, and similar causes. But things are all backwards now—your plant may be as busy in June and July as it is any other months of the year. Your previous summer schedule may be upset, and you'll have to work your way onto a new basis.

Remember that you can't go on doing as you've been doing, whether or not conditions change, nor can you pattern too closely the practice of the fellow across town. The important thing is to get the fixing up done—to get that undesired rider off your back—but use the mule's method, not the horse's. Plan ahead for maintenance at an expected low spot, or do a little at a time, but get the job done. That'll save your own hide.

George Edwards

GEORGE EDWARDS,
Engineer

Cutler-Hammer Control masters this giant of all machine tools

This extremely compact unit of Cutler-Hammer Motor Control is standard equipment of many small motorized machines. Push button operated with thermal overload protection. Simple to install. Fool-proof in operation. Dependable in service. Catalog No. 9103.

your smallest motor needs such protection

When the designers of the record breaking 40 foot boring mill selected Cutler-Hammer Motor Control for this giant of Industry, they testified once again to the overwhelming preference for Cutler-Hammer among experienced engineers. But one fact must not be overlooked. The importance of any electric motor or the machine it drives is measured by the duty it performs, not by its size. Experienced engineers will tell you your smallest motor deserves the same dependable protection . . . Cutler-Hammer Motor Control. CUTLER-HAMMER, Inc., Pioneer Manufacturers of Electric Control Apparatus, 1358 St. Paul Ave., Milwaukee, Wis.

CUTLER-HAMMER
MOTOR CONTROL
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(THIS ADVERTISEMENT APPEARS IN THE SATURDAY EVENING POST JUNE 26, 1937 ISSUE)

NEW BULLETINS

Plastic Cements—Botfield Refractories Co., Swanson & Clymer St., Philadelphia, Pa. Three folders: "Ada-Stic", describing a plastic insulating cement; "Adamant Firebrick Cement"; and "Adachrome", plastic chrome cement. Instructions on application and use.

Air Coolers—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Leaflet 20564-A on coolers for air or other gas for turbo generators, synchronous condensers, waterwheel generators, etc.

Oil-Burning System—Simplex Oil Heating Corp., 30 Church St., New York, N. Y. 4-page Bulletin 119-37 describes automatic and semi-automatic oil-burning systems. Illustrated, size and capacity table.

Small Electrical Instruments—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. 16-page catalog section No. 43-350 describes "miniature panel instruments" for a.c., d.c., rectox and radio frequency. Applications, construction, operation, dimensions, wiring diagrams, ratings, and prices.

Water-Level Gage—Reliance Gauge Column Co. 5902 Carnegie Ave., Cleveland, Ohio. 4-page folder on remote-reading gage which uses special fluid and construction for high visibility.

Tube-Oxidation Data—Steel and Tube Div., Timken Roller Bearing Co., Canton, Ohio. Technical bulletin No. 10 gives data on loss in weight during oxidation at 1,000, 1,250 and 1,500 deg. F. for 13 different alloy-steel tubes.

Stokers—Canton Stoker Corp., Andrews Place, Canton, Ohio. 8-page bulletin 30-G3 describes ram-type underfeed, worm-type underfeed, and natural-draft overfeed stokers. Illustrations, construction details, and operation data.

Water Softener—Elgin Softener Corp., Elgin, Ill. Bulletin 600 shows two-flow zeolite softener recently developed. Describes construction and operation.

Overload Protector for Circuit Breakers—I-T-E Circuit Breaker Co., 19th and Hamilton Sts., Philadelphia, Pa. Bulletin 237 on thermo-magnetic overload protection for a.c. circuit breakers.

Air Heaters—Airtherm Mfg. Co., 1474 S. Vandeventer St., St. Louis, Mo. 16-page bulletin on three types of air heaters for both floor and ceiling mounting. Complete operating data, including cu.ft. of air delivered per min., condensation in lb. per hr., final air temperatures, B.t.u. per hr., etc.

Cycle Counters—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. 4-page catalog section No. 41-375 shows cycle counter for indicating time of operation of any apparatus which will or can be arranged to open or close on a.c. circuit of known frequency.

Polyphase Induction Motors—Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill. Bulletin 1600 describes polyphase, wound-rotor or slip-ring, ball-bearing induction motors with high starting torque and low starting-current characteristics. Illustrated.

Hoists—Harnischfeger Corp., 4400 W. National Ave., Milwaukee, Wis. Bulletin H-5, "P&H Hoists", lists ratings and ranges for hoists from 100-lb. to 15-ton capacity, specifications and electrical accessories.

Welders—Lincoln Electric Co., Cleveland, Ohio. 4-page folder on Model S-6018 engine-driven electric-arc welding unit.

Stokers—Combustion Engineering Co., Inc., 200 Madison Ave., New York, N. Y. 8-page bulletin describes stationary-grate stokers for capacities up to 300 lb. per hr. and moving-grate type for capacities up to 2,000 lb. per hr. Both use screw and ram feed. Includes coal per hr. table, equivalent steam and hot-water radiation supplied, developed boiler hp., stoker and furnace dimensions, setting heights, and diagrams of typical settings.

Air-Conditioning Units—Feeders Mfg. Co., Buffalo, N. Y. 36-page Catalog AC-201 illustrates and describes units built in capacities from 3 tons up, for use either with refrigerant, cold or hot water, or steam. Well illustrated, complete rating and specification tables.

Electric-Motor Bearings—Johnson Bronze Co., New Castle, Pa. Bulletin EM-7 illustrates and describes over 200 bearings with specifications. 40 pages, indexed.

Solenoid Valves—Automatic Switch Co., 154 Grand St., New York, N. Y. 32-page Catalog 20 describes automatic and remote-control valves for air gas steam and liquids. Illustrated, with specification and dimension charts.

NEW PLANT CONSTRUCTION

McGraw-Hill Business News Department Is Prepared to Furnish a More Complete Daily Service

Ala., Sailtpa — Clarke-Washington Electric Membership Corp., c/o R. E. A. Montgomery, making plans diesel engine electric generating plant. $30,000. Private plans.

Calif., Sacramento—Pacific Gas & Electric Co., 245 Market St., San Francisco, power improvements in Sacramento division, incl. erection of 60 kv. sub-station at Garden Valley to be equipped with three 1,000 kva. transformers, 6½ mi. of line will be built from American River power house to sub-station site, total cost $55,000; rebuilding Coast Rock sub-station, approximately 5,000 lin. ft. concrete canal lining, new gas mains installed in various areas in Sacramento Division, own forces. Total est. $154,000. Private plans.

Calif., San Francisco—Pacific Gas & Electric Co., 245 Market St., 1 story, rein.-con. sub-station, 9th Ave. and Judah St., day labor. $20,000 exclusive of equipment.

Ga., Elberton—Georgia Power Co., 75 Marietta St. N. W., Atlanta, plans improvements to Beaver Dam sub-station. $50,000 incl. equipment.

Ill., Chicago—Carnegie-Illinois Steel Corp., 208 South LaSalle St., soon lets contract constructing 125x215 ft. power plant, 88 ft. high, incl. water intakes from Lake Michigan on pile foundations, also 30x70 ft. sub-station, 3400 East 89th St., United Engineers & Constructors, 140 Arch St., Phila., Pa., engrs.

Ill., Springfield—City, c/o J. Knapp, mayor, soon takes bids installing complete steam generating unit in power plant. $180,000. Burns & McDonnell, 107 West Linwood Ave., Kansas City, Mo., engrs.

Ind., Muncie—Indiana General Service Co., W. O. Haymond, div. mgr., plans doubling capacity of Delaware sub-station, increasing power to 100,000 hp. and other needed equipment. $400,000.

Ind., Newcastle—Public Service Co. of Indiana, P. A. McLeod, div. supt., soon takes bids 1 story, sub-station addition to house 12,500 k.v.a. rotary condenser. I Ave. $150,000. Private plans. Indiana Public Service Comn. approved project. Maturity in spring or early summer.

Ind., Terre Haute—Public Service Corp., Terre Haute, plans doubling capacity of power plant at Dresser near here. $4,775,000.

Ia., Bellevue—Bids May 28, City, L. J. Gaylor, clk., furnishing 500 hp. diesel engine equipped with generator, switchboard, piping and wiring, foundation for engine, and altering power house.

Ia., Conn Rapids—City rejected proposal to grant 10 year franchise to Iowa Electric Light & Power Co., and will construct municipal light and power plant. Iowa Electric Light & Power Co. lost suit to stop construction of city plant.

Ia., Hopkinton—Bids May 25, by City, constructing 40x50 ft., brick, concrete, steel, wood power plant; 2 diesel engine generator units, either medium speed or high speed with auxiliary apparatus, constructed of cast iron, steel and non-ferrous metals; switchboard and power wiring; electrical distribution system, incl. consumers meters, services, constructed on wood poles and cross arms, with copper wires. A. S. Harrington, Baum Bldg., Omaha, Neb., consult. engr.

Ia., Rockwell City—City plans municipal power and light plant. Iowa Public Service Corp. obtained injunction in District Court stopping the above construction and this has just been reversed by Iowa Supreme Court.

Ia., Webster City — City plans enlarging power plant, incl. purchasing steam turbine and addition to building. $100,900.

Kan., Topeka—Hill Packing Co., foot of Jefferson St., 1 story, 65x96 ft., brick, steel, rein.-con. warehouse, power plant, boilers and engines, 2nd floor, brick, rein.-con. addition to packing plant, incl. boning room and sharp freezer. Owner builds. $35,000. B. W. Friedel, archt. Owner also plans purchasing machinery for meat packing plant and rendering works, engines (steam) compressors and coils, etc.

Kan., Washington—City, c/o A. N. Halloway, mayor, approved $88,000 bonds constructing municipal power and light plant. E. T. Archer & Co., 609 New England Bldg., Kansas City, Mo., engrs.

Md., Cumberland—Potomac Edison Co., Hagerstown, making plans rein.-con. brick power plant addition. $3,000,000. Private plans.

Mass., Gardner—Heywood Wakefield Co., 206 Central St., plans prepared by F. J. Sill, East Main St., Westboro, and soon lets general contract 2 story, 30x65 ft., brick, steel power plant. $40,000. Steel work awarded to Eastern Bridge & Structural Co., 88 Crescent St., Worcester.

Mass., South Boston—Edison Electric Illuminating Co., F. D. Comerford, pres., 182 Tremont St., Boston, making plans power plant extension, L St., incl. generating units, boilers and equipment. Equipment includes 25 M kilowatt generator, two 300 M lb. per hour high pressure boilers fixed by pulverized coal. Generator, to Westinghouse Electric & Mfg. Co., 10 High St., Boston.

Mich., Owosso—City, W. Bennet, comr., defeated $375,000 bonds for 2 story, basement, brick, steel, concrete power plant.

Neb., Auburn—City Light Dpt. voted to purchase local plant owned by Western Public Service Co. by condemnation proceedings. State Supreme Court appointed three to act as appraisers for this purchase. On acquiring the property, considerable improvements and new equipment will be needed. $50,000.

Neb., Fremont—City, Dpt. P. Utilities, L. D. Wright, supt., plans constructing power plant, metal clad switchboard and appurtenances, 2,000 ft. underground service, several miles of 33,000 volt transmission line with substation. $300,000. G. Grabe, Fremont, archt. Black & Veatch, 4706 Bway, Kansas City, Mo., consult. engrs.

Neb., Lincoln—City Council voted to construct light plant improvements, incl. switchboard, new building, changes inside the plant. $175,000. Applied for P.W.A. funds. D. L. Erickson, city engr. Black & Veatch, 4706 Bway., Kansas City, Mo., consult. engrs.

N. Y., Albany—Niagara Hudson Power Corp., 15 Broad St., New York, plans steam power plant on Hudson River, near here. To exceed $500,000 with equipment. Part of $100,000,000 5 year construction program.

N. Y., New York—News York Steam Corp., 130 East 15th St., plans by W. H. Paine, c/o owner, altering 2 story steam plant, 407 East 35th St. $40,000 with equipment.

O., Cincinnati—Bruckmann Brewing Co., Ludlow Ave., plans power plant and brewery. To exceed $40,000. Fosdick & Hilmer, Union Trust Bldg., engrs.

O., Findlay—Ohio Utilities Comn. has authorized Central Light & Power Co., Findlay, to issue and sell bonds and notes to help finance construction 10,000 kw. steam generating plant. $1,200,000.

O., Wapakoneta—City, C. B. Miller, Safety and Service Director, plans electric light and power generating plant. $40,000. Burns & McDonell, 307 East 4th St., Cincinnati, engrs.

Okla., Blackwell—City, D. Randall, clk., soon takes bids improving existing power plant, incl. 4,000 kw. turbine generator and building. $300,000. Black & Veatch, 4706 Bway., Kansas City, Mo., engrs.

Pa., Chambersburg — Municipality plans electric power and light plant addition. To exceed $40,000.

Pa., Danville—Borough Council, Boro Hall, plans purchasing uniflow steam engine with generator and excitor for installation in municipal light and power plant. $11,000. Maturity soon.

Pa., Edinboro—Commonwealth of Pennsylvania, State Teachers College, C. Ross, pres., plans by R. Irvin, archt. and engr., 102 Vandergrift Bldg., Pittsburgh, power plant at State Teachers College, incl. water and steam lines, sewers, emergency lighting system. $160,000. P.W.A. aid contemplated.

Pa., Polk—Commonwealth of Pennsylvania, Polk State School, Dr. D. M. Watkins, supt., 600 North 2nd St., Harrisburg, sketches power house improvements. $90,000. Will apply for P.W.A. funds. H. B. Joyce, 810 Commerce St., Erie, engr.

S. D., Parker—Municipal Light and Power Plant, election in May to vote on purchase of new power generating unit.

Tex., Floydada—Floyd County Cooperative Rural Electrification Project plans constructing and equipping large electric generating plant. $1,150,000, also 450 mi. power transmission (electric) lines into rural communities throughout the county. $450,000. Requests have been filed with Rural Electrification Administration at Washington for funds. W. G. Morrison, 204 Prof. Bldg., Waco, engr.

Wash., Tacoma—City plans electric light and power plant improvements and additions, East 11th St. Station. $55,000.

Man., Winnipeg—Bids May 25, by G. F. Bentley, city clk., supplying installing one hydraulic turbine and one 10,000 kva. generator at Winnipeg Hydro-Electric System's Slave Falls plant.

Ont., Chatham — Chatham Hydro-Electric Utilities making plans warehouse and substation. J. Mathew, Chatham, archt.

Que., St. Lambert—Montreal Light, Heat & Power Co., 107 Craig W., Montreal, making plans outdoor sub-station, Oak Ave. $50,000. Private plans. Owner will purchase all equipment.

Uruguay, Montevideo—Ministry of Relations accepts plans for constructing hydro-electric plant on Negro River. $33,000,000.

England, Liverpool — Municipality voted $1,500,000 for extension to electrical system.